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[TITLE OF THE INVENTION]

An Electron-Emitting Device and the Method of Manufacturing the Same, and An Electron Source and Image-Forming Apparatus Using the Electron-Emitting Device

[WHAT IS CLAIMED IS]

[Claim 1]

An electron-emitting device comprising a pair of oppositely disposed device electrodes and a thin film including an electron-emitting region on a substrate, characterized in that the vicinity of said electron-emitting region is coated with a coat containing carbon as a principal ingredient.

[Claim 2]

An electron-emitting device comprising a pair of oppositely disposed device electrodes and a thin film including an electron-emitting region on a substrate, characterized in that the higher potential side than a part of said electron-emitting region is coated with a coat containing carbon as a principal ingredient.

[Claim 3]

The electron-emitting device according to claim 1 or 2, wherein said thin film including said electron-emitting region comprises electroconductive fine particles.

[Claim 4]

The electron-emitting device according to claim 3, wherein said electroconductive fine particles are a metal or an oxide of metal.

[Claim 5]

The electron-emitting device according to claim 3, wherein said coat containing carbon as a principal ingredient covers at least a part of said electroconductive fine particles.

[Claim 6]

The electron-emitting device according to claim 1 or 2, wherein said electron-emitting region comprises electroconductive fine particles.

[Claim 7]

The electron-emitting device according to claim 6, wherein said coat containing carbon as a principal ingredient covers at least a part of electroconductive fine particles of said electron-emitting region.

[Claim 8]

The electron-emitting device according to claim 1 or 2, wherein said coat containing carbon as a principal ingredient covers at least a part of said device electrodes.

[Claim 9]

The electron-emitting device according to claim 1 or 2, wherein said coat containing carbon as a principal ingredient comprises graphite, amorphous carbon or a mixture thereof.

[Claim 10]

A method of manufacturing an electron-emitting device comprising a pair of oppositely disposed device electrodes and a thin film including an electron-emitting region on a substrate, which comprises the steps of forming said pair of device electrodes, forming said thin film including an electron-emitting region, conducting an electric forming process and conducting an activation process.

[Claim 11]

The method of manufacturing an electron-emitting device according to claim 10, wherein said activation process comprises the step of providing a coat containing carbon as a principal ingredient on an electron-emitting device after conducting said electric forming process.

[Claim 12]

The method of manufacturing an electron-emitting device according to claim 10 or 11, wherein said activation process comprises the step of applying a voltage above a voltage-controlled-negative-resistance region in a vacuum to said pair of electrodes of said electron-emitting device.

[Claim 13]

The method of manufacturing an electron-emitting device according to claim 12, wherein said voltage is applied in the form of pulse.

[Claim 14]

The method of manufacturing an electron-emitting device according to claim 13, wherein said voltage is a drive voltage of an electron-emitting device.

[Claim 15]

An electron source designed to emit electrons in accordance with input signals, characterized in that a plurality of electron-emitting devices according to claim 1 or 2 are arranged on a substrate.

[Claim 16]

The electron source according to claim 15, wherein said plurality of electron-emitting devices are arranged in rows, each device being connected to wirings at opposite ends, and a modulation means is provided.

[Claim 17]

The electron source according to claim 15, wherein said pairs of device electrodes of the plurality of electron-emitting devices are respectively connected to m of insulated X-directional wirings and n of insulated Y-directional wirings.

[Claim 18]

An image-forming apparatus for forming image according to input signals, characterized in that said apparatus comprises at least image forming members and an electron source according to any one of claims 15 to 17.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Industrial Utilization]

This invention relates to an electron source and an image-forming apparatus such as a display apparatus incorporating an electron source and, more particularly, it relates to a novel surface conduction electron-emitting device as well as a novel electron source and an image-forming apparatus such as a display apparatus incorporating such an electron source.

[0002]

[Prior Art]

There have been known two types of electron-emitting device; the thermoelectron type and the cold cathode type. Of these, the cold cathode type include the field emission type (hereinafter referred to as the FE-type), the metal/insulation layer/metal type (hereinafter referred to as the MIM-type) and the surface conduction type (hereinafter referred to as the SCE).

[0003]

Examples of the FE electron-emitting device are described in W. P. Dyke & W. W. Dolan, "Field emission", Advance in Electron Physics, 8, 89 (1956) and C. A. Spindt, "PHYSICAL Properties of thin-film field emission cathodes with molybdenum cones", J. Appl. Phys., 47, 5284 (1976).

[0004]

MIM devices are disclosed in papers including

C. A. Mead, "The tunnel-emission amplifier", J. Appl. Phys., 32, 646 (1961).

[0005]

SCE devices are proposed in papers including M. I. Elinson, Radio Eng. Electron Phys., 10 (1965).

[0006]

An SCE device is realized by utilizing the phenomenon that electrons are emitted out of a small thin film formed on a substrate when an electric current is forced to flow in parallel with the film surface. While Elinson proposes the use of SnO_2 thin film for a device of this type, the use of Au thin film is proposed in [G. Dittmer: "Thin Solid Films", 9, 317 (1972)] whereas the use of In_2O_3/SnO_2 and that of carbon thin film are discussed respectively in [M. Hartwell and C. G. Fonstad: "IEEE Trans. ED Conf.", 519 (1975)] and [H. Araki et al.: "Vacuum", Vol. 26, No. 1, p. 22 (1983)].

[0007]

Fig. 18 of the accompanying drawings schematically illustrates a typical surface-conduction electron-emitting device proposed by M. Hartwell. In Fig. 18, reference numeral 1 denotes a substrate. Reference numeral 2 denotes an electrically conductive thin film normally prepared by producing an H-shaped thin metal oxide film by means of sputtering, part of which eventually makes an electron-emitting region 3 when it is subjected to an electrically energizing process referred to as "electric

forming" as described hereinafter. In Fig. 18, the thin film 4 including an electron-emitting region has a length L1 of 0.5 to 1 mm and a width W of 0.1 mm.

[0008]

As described above, the conductive film 2 of such a surface conduction electron-emitting device is normally subjected to an electrically energizing preliminary process, which is referred to as "electric forming", to produce an electron-emitting region 3. In the electric forming process, a DC voltage or a slowly rising voltage that rises typically at a rate of 1 V/min. is applied to given opposite ends of the conductive film 2 to partly destroy, deform or transform the thin film and produce an electron-emitting region 3 which is electrically highly resistive. Thus, the electron-emitting region 3 is part of the conductive film 2 that typically contains fissures therein so that electrons may be emitted from those fissures. The thin film 2 containing an electron-emitting region that has been prepared by electric forming is hereinafter referred to as a thin film 4 inclusive of an electron-emitting region. Note that, once subjected to an electric forming process, a surface conduction electron-emitting device comes to emit electrons from its electron-emitting region 3 whenever an appropriate voltage is applied to the thin film 4 inclusive of the electron-emitting region to make an electric current run through the device.

[0009]

Known surface conduction electron-emitting devices having a configuration as described above are accompanied by various problems and however, the present inventors have made intensive studies for improvements, which will be described hereinafter, and solved the various problems when the devices are put to practical use.

[0010]

Since a surface conduction electron-emitting device as described above is structurally simple and can be manufactured in a simple manner, a large number of such devices can advantageously be arranged on a large area without difficulty. As a matter of fact, a number of studies have been made to fully exploit this advantage of surface conduction electron-emitting devices. Applications of devices of the type under consideration include charged electron beam sources and electronic displays.

[0011]

In typical examples of application involving a large number of surface conduction electron-emitting devices, the devices are arranged in parallel rows and each of the devices are respectively connected at given opposite ends with wirings that are arranged in columns to form an electron source (as disclosed in Japanese Patent Application Laid-open No. 64-31332. As for display apparatuses and other image-forming apparatuses comprising surface conduction electron-emitting devices such as electronic displays,

although flat-panel type dispalys comprising a liquid crystal panel in place of a CRT have gained popularity in recent years, such displays are not without problems. One of the problems is that a light source needs to be additionally incorporated into the display in order to illuminate the liquid crystal panel because the display is not of the so-called emission type and, therefore, the development of emission type display apparatuses has been eagerly expected in the industry. An emission type electronic display that is free from this problem can be realized by using a light source prepared by arranging a large number of surface conduction electron-emitting devices in combination with fluorescent bodies that are made to shed visible light by electrons emitted from the electron source. Even if such apparatus has a large display area, it can be relatively easily produced and is an emission type display apparatus excellent in display quality. (See, for example, United States Patent No. 5,066,883)

[0012]

In a conventional light source comprising a large number of surface conduction electron-emitting devices arranged in the form of a matrix, devices are selected for electron emission and subsequent light emission of fluorescent bodies by applying drive signals to appropriate row-directed wirings (row-directional wiring) connecting respective rows of surface conduction electron-emitting

devices in parallel, column-directed wirings (column-directional wiring) connecting respective columns of surface conduction electron-emitting devices in parallel and control electrodes (or grids) arranged within a space separating the electron source and the fluorescent bodies along the direction of the columns of surface conduction electron-emitting devices of a direction perpendicular to that of the rows of devices (See, for example, Japanese Patent Application Laid-open No. 1-283749).

[0013]

[Problems to be Solved by the Invention]

However, little has been known about the behavior in vacuum of a surface conduction electron-emitting device to be used for an electron source and an image-forming apparatus incorporating such an electron source and, therefore, it has been desired to provide surface conduction electron-emitting devices that have stable electron-emitting characteristics and hence can be operated efficiently in a controlled manner.

[0014]

The efficiency of a surface conduction electron-emitting device is defined for the purpose of the present invention as the ratio of the electric current running between the pair of device electrodes of the device (hereinafter referred to device current If) to the electric current produced by the emission of electrons into vacuum (hereinafter referred to emission current Ie).

[0015]

It is desired to have a large emission current with a small device current.

[0016]

Thus, a low electricity consuming high quality image-forming apparatus typically comprising an image-forming member of fluorescent bodies can be realized if there provided a surface conduction electron-emitting device that has stable electron-emitting characteristics and hence can be operated efficiently in a controlled manner. Such an improved image-forming apparatus may be a very flat television set. A low energy consuming image-forming apparatus may require less costly drive circuits and other related components. In view of the above described circumstances, it is therefore an object of the present invention to provide a novel and highly efficient electron-emitting device and a novel method of manufacturing the same well as a novel electron source incorporating such an electron-emitting and an image-forming apparatus such as a display apparatus using such an electron source.

[0017]

[Means for Solving the Problems]

In order to solve the above-mentioned problems, the present invention provides a method of manufacturing a surface conduction electron-emitting device comprising a pair of oppositely disposed device electrodes and a thin film including an electron-emitting region arranged on a

substrate, characterized in that a coat containing carbon as a principal ingredient is coated on and around the electron-emitting region, preferably, the coat containing carbon as a principal ingredient may be formed on the high voltage side from part of the electron-emitting region, more preferably, the thin film having the electron-emitting device comprises conductive fine particles such as metals or metal oxides, the coat containing carbon as a principal ingredient is coated on at least a part of the conductive fine particles, the electron-emitting region is comprised of the condutive fine particles, at least a part of the conductive fine particles of the electron-emitting region is coated with the coat containing carbon as a principal ingredient, and at least a part of the device electrodes may also be coated therewith。

[0018]

The coat containing carbon as a principal ingredient comprises graphite, amorphous carbon or a mixture thereof。

[0019]

The method for manufacturing the above-mentioned electron-emitting device comprises at least steps of forming a pair of electrodes, forming a thin film including an electron-emitting region, preferably, conducting an electric forming process and conducting an activation process, wherein the activation process comprises steps of forming a coat containing carbon as a principal ingredient

on the thin film and applying in a vacuum a voltage exceeding the voltage-controlled-negative-resistance level to the pair of electrodes of the device.

[0020]

Further, the applied voltage is preferably a pulse voltage, more preferably a drive voltage of an electron-emitting device.

[0021]

Further, the present invention provides an electron source designed to emit electrons in accordance to input signals and comprising a plurality of electron-emitting devices of the above described type on a substrate, wherein the electron-emitting devices are arranged in rows, each device being connected to wirings at opposite ends, and a modulation means is provided for them or, alternatively, the pairs of device electrodes of the electron-emitting devices are respectively connected to m insulated X-directional wirings and n insulated Y-directional wirings, the electron-emitting devices being arranged in rows having a plurality of devices.

[0022]

Still further, the present invention provides an image forming apparatus for forming images according to input signals, wherein the apparatus comprises at least image-forming members and an electron source according to the invention.

[0023]

The basic configuration of the surface conduction electron-emitting device according to the present invention will be described below.

[0024]

Figs. 1(a) and 1(b) are schematic plan and sectional side views showing the basic configuration of a surface conduction electron-emitting device according to the invention. The basic configuration of the device according to the present invention will be described by referring to Fig. 1.

[0025]

In Fig. 1, the device comprises a substrate 1, a pair of device electrodes 5 and 6, a thin film 4 including an electron-emitting region, an electron-emitting region 3.

[0026]

Materials that can be used for the substrate 1 include quartz glass, glass containing impurities such as Na to a reduced concentration level, soda lime glass, glass substrate realized by forming an SiO_2 layer on soda lime glass by means of sputtering, ceramic substances such as alumina.

[0027]

While the oppositely arranged device electrodes 5 and 6 may be made of any conducting material, preferred candidate materials include metals such as Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu and Pd and their alloys, printable

conducting materials made of a metal or a metal oxide selected from Pd, Ag, RuO_2, Pd-Ag and glass, transparent conducting materials such as In_2O_3-SnO_2 and semiconductor materials such as poly-silicon.

[0028]

The distance L1 separating the device electrodes is preferably between several hundreds angstroms and several hundreds micrometers and, still preferably, between several micrometers and tens of several micrometers depending on photolithography technique that is a basic manufacturing method of a device electrode, namely, the performance of an exposure machine and etching method, and depending on the voltage to be applied to the device electrodes and the field strength available for electron emission.

[0029]

The length W1 of the device electrodes and the film thickness d of the device electrodes 5 and 6 are appropriately determined depending on the resistance of electrodes, connecting wire with the above-mentioned X and Y wirings, and arrangement of a large number of electron sources. The length W1 of the device electrodes 5 and 6 is usually between several micrometers and hundreds of several micrometers and the film thickness d of the device electrodes 5 and 6 is between hundreds of several angstroms and several micrometers.

[0030]

The thin film including an electron-emitting region arranged between and on a pair of oppositely disposed device electrodes 5 and 6, on a substrate 1 contains an electron-emitting region 3, and however, such thin film is not always arranged on the device electrodes 5 and 6 as shown in Fig. 1(b). That is, the thin film 2 for forming an electron-emitting region and a pair of oppositely disposed device electrodes 5 and are successively laminated on an insulation substrate 1. All area between oppositely disposed device electrodes 5 and 6 sometimes acts as the function of electron-emitting region. The thickness of thin film 4 including an electron-emitting region is determined as a function of the stepped coverage of the thin film on the device electrodes 5 and 6, the electric resistance between the device electrodes 5 and 6, and electron-emitting region 3, the particle diameter of the electroconductive fine particles of the electron-emitting region 3, and the parameters for the forming operation that will be described later as well as other factors and preferably between several angstroms and ten hundreds of several angstroms and more preferably between 10 angstroms and 500 angstroms. The thin film 4 normally shows a resistance per unit surface area between 10^3 and 10^7 Ω/□.

[0031]

The thin film 4 including the electron-emitting

region is made of fine particles of a material selected from metals such as Pd, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W and Pb, oxides such as PdO, SnO_2, In_2O_3, PbO and Sb_2O_3, borides such as HfB_2, ZrB_2, LaB_6, CeB_6, YB_4 and GdB_4, carbides such as TiC, ZrC, HfC, TaC, SiC and WC, nitrides such as TiN, ZrN and HfN, semiconductors such as Si and Ge, carbon, AgMg, NiCa, Pb and Sn.

[0032]

The term "a fine particle film" as used herein refers to a thin film constituted of a large number of fine particles that may be loosely dispersed, tightly arranged or mutually and randomly overlapping (to form an island structure under certain conditions).

[0033]

The diameter of fine particles is between a several angstroms and thousands of several angstroms and preferably between 10 angstroms and 200 angstroms.

[0034]

The electron-emitting region 3 may contain a large number of electroconductive fine particles having a diameter between several angstroms and hundreds of several angstroms, preferably 10 angstroms and 500 angstroms, although it is dependent on the thickness of the electroconductive thin film 4 including an electron-emitting region and the electric forming process which will be described hereinafter.

[0035]

The material of the electron-emitting region 3 may be

selected from all or part of the materials that can be used to prepare the thin film 4 including the electron-emitting region.

[0036]

While various methods may be conceivable for manufacturing an electron-emitting device including an electron-emitting region 3, Fig. 2 illustrates a typical one of such methods. In Fig. 2, reference numeral 2 denotes a thin film for forming an electron-emitting region, for example, fine particle film is mentioned.

[0037]

Now, a method of manufacturing will be described by referring to Figs. 1 and 2.

1) After thoroughly cleansing a substrate 1 with detergent, pure water and organic solvent, a device electrode material is deposited on the insulation substrate 1 by means of vacuum deposition, sputtering or some other appropriate technique for a pair of device electrodes 5 and 6, which are then produced by photolithography (Fig. 2(a)).

2) An organic metal thin film is formed between the pair of device electrodes 5 and 6 provided on the insulation substrate 1 by applying an organic metal solution and leaving the applied solution for a given period of time. An organic metal solution as used herein refers to a solution of an organic compound containing as a principal ingredient a metal selected from the group of metals cited above including Pd, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn,

Ta, W and Pb. Thereafter, the organic metal thin film is heated, sintered and subsequently subjected to a patterning operation, using an appropriate technique such as lift-off or etching, to produce a thin film 2 for forming an electron-emitting region (Fig. 2(b)). While an organic metal solution is used to produce a thin film in the above description, a thin film may alternatively be formed by vacuum deposition, sputtering, chemical vapor phase deposition, dispersed application, dipping, spinner or some other technique.

3) Thereafter, the device electrodes 5 and 6 are subjected to an electrically energizing process referred to as "forming", where a pulse voltage or a rising voltage is applied to the device electrodes 5 and 6 from a power source (not shown) to produce an electron-emitting region 3 in the thin film 2 forming an electron-emitting region (Fig. 2(c)). The area of the thin film 2 for forming an electron-emitting region that has been locally destroyed, deformed or transformed to undergo a structural change is referred to as an electron-emitting region 3. As described above, the present inventors consider that the electron-emitting region 3 is comprised of the electroconductive line particles.

[0038]

All the remaining steps of the electric processing after the forming operation are carried out by using a gauging system which will be described below by referring

to Fig. 3.

[0039]

Fig. 3 is a schematic block diagram of a gauging system for determining the performance of an electron-emitting device having a configuration as illustrated in Fig. 1. In Fig. 3, the device comprises a substrate 1, a pair of device electrodes 5 and 6, a thin film 4 including an electron-emitting region, and an electron-emitting region 3. Otherwise, the gauging system comprises a power source 31 for applying a device voltage Vf to the device, an ammeter 30 for metering the device current If running through the thin film 4 including the electron-emitting region between the device electrodes 5 and 6, an anode 34 for capturing the emission current Ie emitted from the electron-emitting region of the device, a high voltage source 33 for applying a voltage to the anode 34 of the gauging system and another ammeter 32 for metering the emission current Ie emitted from the electron-emitting region 3 of the device.

[0040]

For measuring the device current If and the emission current Ie, the device electrodes 5 and 6 are connected to the power source 31 and the ammeter 30 and the anode 34 is placed above the device and connected to the power source 33 by way of the ammeter 32. The electron-emitting device to be tested and the anode 34 are put into a vacuum chamber, which is provided with an exhaust pump, a vacuum gauge and other

pieces of equipment necessary to operate a vacuum chamber so that the metering operation can be conducted under a desired vacuum condition. The exhaust pump may be provided with an ordinary high vacuum system comprising a turbo pump or a rotary pump and an ultra-high vacuum system comprising an ion pump. The vacuum chamber and the substrate of the electron source can be heated to approximately 200°C by means of a heater (not shown).

[0041]

For determining the performance of the device, a voltage between 1 and 10 kV is applied to the anode, which is spaced apart from the electron-emitting device by distance H which is between 2 and 8 mm.

[0042]

For the forming operation, a constant pulse voltage or a increasing pulse voltage may be applied. The operation of using a constant pulse voltage will be described first by referring to Fig. 4(a), showing a pulse voltage having a constant pulse height.

[0043]

In Fig. 4(a), the pulse voltage has a pulse width T1 and a pulse interval T2, which are between 1 microsecond and 10 milliseconds and between 10 microseconds and 100 milliseconds respectively. The height of the triangular wave (the peak voltage for the electric forming operation) may be appropriately selected so long as the voltage is applied in vacuum of about 10^{-5} torr.

[0044]

Fig. 4(b) shows a voltage waveform when applying a pulse voltage whose pulse height increases with time.

[0045]

In Fig. 4(b), the voltage waveform has an pulse width T1 and a pulse interval T2, which are between 1 microsecond and 10 milliseconds and between 10 microseconds and 100 milliseconds respectively. The height of the triangular wave (the peak voltage for the electric forming operation) is increased at a rate of, for instance, 0.1 V per step, and the voltage is applied in vacuum at about 10^{-5} torr.

[0046]

The electric forming operation will be terminated when typically a resistance greater than 1 M ohm is observed for the device current running through the thin film 2 for forming an electron-emitting region while applying a voltage of approximately 0.1 V is applied to the device electrodes to locally destroy or deform the thin film. The voltage observed when the electric forming operation is terminated is referred to as the forming voltage Vf.

[0047]

While a triangular pulse voltage is applied to the device electrodes to form an electron-emitting region in an electric forming operation as described above, the pulse voltage may have a different wave form such as rectangular

form and the pulse width and the pulse interval may be of values other than those cited above so long as they are selected as a function of the device resistance and other values that meet the requirements for forming an electron-emitting region.

4) After the electric forming operation, the device is subjected to an activation process, where a pulse voltage having a constant wave height is repeatedly applied to the device in vacuum of about 10^{-4} to 10^{-5} torr as in the case of the forming operation so that carbon and carbon compounds may be deposited on the device out of the organic substances existing in the vacuum in order to cause the device current If and the emission current Ie of the device to change markedly. The activation process is terminated when the emission current Ie gets to a sacturation point while gauging the device current If and the emission current Ie. Fig. 5 typically shows how the device current If and the emission current Ie are dependent on the duration of the activation process.

[0048]

It should also be noted that, in the activation process, the time dependency of the device current If and the emission current Ie varies as a function of the degree of vacuum and the pulse voltage applied to the device and that the contour and the state of the deformed or transformed portion of the thin film depend on how the forming process is carried out.

[0049]

The activation process is referred to as a high resistance activation process when the pulse voltage used in the process is sufficiently high relative to the forming voltage Vf, whereas it is referred to as a low resistance activation process when the pulse voltage used in the process is sufficiently low relative to the forming voltage Vform. More specifically, the initial voltage VP that indicates the voltage controlled negative resistance of the device as defined hereinafter provides a reference for the above distinction.

[0050]

Fig. 6 schematically illustrates how an electron-emitting device according to the invention is treated in the high and low resistance activation processes when observed through an FESEM or TEM.

[0051]

Fig. 6(a) and 6(b) respectively show schematic cross sectional views of a device treated by a high resistance activation process and a low resistance activation process. In a high resistance activation process (Fig. 6(a)), carbon and/or carbon compounds are remarkably deposited on the high potential side of the device partly beyond the area 3 deformed or transformed by electric forming, whereas they are only slightly deposited on the low potential side of the device. When observed through a microscope having large magnifying power, a deposit of carbon and/or carbon compounds

is found on and near some of the fine particles of the device and, in some cases, even on the device electrodes if the electrodes are located relatively close to each other. The thickness of the film deposit is preferably less than 500 angstroms and more preferably less than 300 angstroms.

[0052]

When observed through a TEM or Roman microscope, it is found that the deposited carbon and carbon compounds are mostly graphite (both mono- and poly-crystalline) and non-crystalline carbon (or a mixture of non-crystalline carbon and poly-crystalline graphite).

[0053]

In a low resistance activation process (Fig. 6(b)), on the other hand, a deposit of carbon and/or carbon compounds 61 is found only in the area 3 that has been deformed or transformed by electric forming. When observed through a microscope having large magnifying power, a deposit of carbon and/or carbon compounds is also found on and near some of the fine particles of the device.

[0054]

When observed through a TEM or Roman microscope, it is found that the deposited carbon and carbon compounds are mostly graphite (both mono- and poly-crystalline) and non-crystalline carbon (or a mixture of non-crystalline carbon and poly-crystalline graphite).

5) An electron-emitting device that has been treated in an electric forming process and an activation process is then driven to operate in a vacuum of a degree higher than that of the activation process. Here, a vacuum of a degree higher than that of the activation process means a vacuum of a degree greater than about 10^{-6} torr and, preferably, an ultra-high vacuum where no carbon nor carbon compounds cannot be additionally deposited on the device.

[0055]

Thus, no carbon nor carbon compounds would be deposited thereafter to establish stable device and emission currents If and Ie.

[0056]

In the high and low resistance activation processes, the stabilities at initial driving are different from each other, and therefore, it is more preferred that the high resistance process is selected for the activation process.

[0057]

Now, some of the basic features of an electron-emitting device according to the invention and prepared in the above described manner will be described below by referring to Figs. 3 and 5.

[0058]

Fig. 7 shows a graph schematically illustrating the relationship between the device voltage Vf and the emission current Ie and the device current If typically observed by the gauging system of Fig. 3. Note that

different units are arbitrarily selected for Ie and If in Fig. 7 in view of the fact that Ie has a magnitude by far smaller than that of If. As seen in Fig. 7, an electron-emitting device according to the invention has three remarkable features in terms of emission current Ie, which will be described below.

[0059]

Firstly, an electron-emitting device according to the invention shows a sudden and sharp increase in the emission current Ie when the voltage applied thereto exceeds a certain level (which is referred to as a threshold voltage hereinafter and indicated by Vth in Fig. 5), whereas the emission current Ie is practically undetectable when the applied voltage is found lower than the threshold value Vth. Differently stated, an electron-emitting device according to the invention is a non-linear device having a clear threshold voltage Vth to the emission current Ie.

[0060]

Secondly, since the emission current Ie is highly dependent on the device voltage Vf, the emission current Ie can be effectively controlled by way of the device voltage Vf.

[0061]

Thirdly, the emitted electric charge captured by the anode 34 is a function of the duration of time of application of the device voltage Vf. In other words, the amount of

electric charge captured by the anode 34 can be effectively controlled by way of the time during which the device voltage Vf is applied.

[0062]

On the other hand, the device current If either monotonically increases relative to the device voltage Vf (as shown by a solid line in Fig. 7, a characteristic referred to as MI characteristic hereinafter) or changes to show a form specific to a voltage-controlled-negative-resistance characteristic (as shown by a broken line in Fig. 5, a characteristic referred to as VCNR characteristic hereinafter). These characteristics of the device current are dependent on a number of factors including the manufacturing method, the conditions where it is gauged and the environment for operating the device. The critical voltage for the VCNR characteristic to become apparent is referred to as the boundary voltage Vp.

[0063]

Thus, it has been discovered that the VCNR characteristic of the device current If varies remarkably as a function of a number of factors including the electric conditions of the electric forming process, the vacuum conditions of the vacuum system, the vacuum and electric conditions of the gauging system particularly when the performance of the electron-emitting device is gauged in the vacuum gauging system after the electric forming process (e.g., the sweep rate at which the voltage being applied to

the electron-emitting device is swept from low to high in order to determine the current-voltage characteristic of the device) and the duration of time for the electron-emitting device to have been left in the vacuum system before the gauging operation. At this time, the emission current Ie shows an MI chracteristics.

[0064]

The electron-emitting device according to the invention has the above-mentioned characteristic of a surface conduction electron-emitting device, namely, a monotonical increase characteristic of the device current If and emission current Ie to the voltage applied to the device, so that it is expected that the device is used in various application field.

[0065]

In the surface conduction electron-emitting device obtained by dispersing the electroconductive fine particles in advance, a part of the basic manufacturing method having a basic device configuration of the invention as described above may be changed.

[0066]

Thus, the basic configuration and the manufacturing method of the surface conduction electron-emitting device are described, and however, according to the present invention, when the surface conduction electron-emitting device has the above-mentioned three remarkable features, there is not limited to the above-mentioned configuration,

and the device can be applied to an electron source and an image forming apparatus such as display apparatus.

[0067]

Now, an electron source and an image-forming apparatus according to the invention will be described.

[0068]

The electron source and an image-forming apparatus can be realized by arranging a plurality of electron-emitting devices according to the invention on a substrate.

[0069]

Electron-emitting devices may be arranged on a substrate in a number of different modes. For instance, a number of surface conduction electron-emitting devices as described earlier by referring to a light source may be arranged in rows along a direction (hereinafter referred to row-direction), each device being connected by wirings at opposite ends thereof, and driven to operate by control electrodes (hereinafter referred to as grids) arranged in a space above the electron-emitting devices along a direction perpendicular to the row direction (hereinafter referred to as column-direction), or, alternatively as described below, a total of m X-directional wiring and a total of n Y-directional wirings are arranged with an interlayer insulation layer disposed between the X-directional wirings and the Y-directional wiring along with a number of surface conduction electron-emitting devices such that the pair of device electrodes of each surface

conduction electron-emitting device are connected respectively to one of the X-directional wiring and one of the Y-directional wirings. The latter arrangement is referred to as a simple matrix arrangement.

[0070]

Now, the simple matrix arrangement will be described in detail.

[0071]

In view of the three basic features of a surface conduction electron-emitting device according to the invention, namely, firstly, an electron-emitting device according to the invention shows a sudden and sharp increase in the emission current Ie when the voltage applied thereto exceeds a certain level (which is referred to as a threshold voltage hereinafter and indicated by Vth in Fig. 5), whereas the emission current Ie is practically undetectable when the applied voltage is found lower than the threshold value Vth. Differently stated, an electron-emitting device according to the invention is a non-linear device having a clear threshold voltage Vth to the emission current Ie.

[0072]

Secondly, since the emission current Ie is highly dependent on the device voltage Vf, the emission current Ie can be effectively controlled by way of the device voltage Vf.

[0073]

Thirdly, the emitted electric charge captured by the anode 34 is a function of the duration of time of application of the device voltage Vf. In other words, the amount of electric charge captured by the anode 34 can be effectively controlled by way of the time during which the device voltage Vf is applied.

[0074]

Further, more preferably, in the surface conduction electron-emitting device, both the device current If and the emission current Ie have a monotonical increase characteristic (MI characteristic) to the voltage applied to the pair of oppositely disposed device electrodes.

[0075]

As described above, the surface conduction electron-emitting devices can be controlled for electron emission by controlling the wave height and the pulse width of the pulse voltage applied to the opposite electrodes of the device above the threshold voltage level. On the other hand, the device does not emit any electron below the threshold voltage level. Therefore, regardless of the number of electron-emitting devices, desired surface conduction electron-emitting devices can be selected and controlled for electron emission in response to the input signal by applying a pulse voltage to each of the selected devices.

[0076]

Fig. 8 is a schematic plan view of the substrate of

an electron source according to the invention realized by using the above feature.

[0077]

There are provided a total of m X-directional wirings 82, which are denoted by DX1, DX2, ..., DXm and made of a conductive metal formed by vacuum deposition, printing or sputtering. These wirings are so designed in terms of material, thickness and width that, if necessary, a substantially equal voltage may be applied to the surface conduction electron-emitting devices. A total of n Y-directional wirings 83 are arranged and donated by DY1, DY2, ..., DYn, which are similar to the X-directional wirings 82 in terms of material, thickness and width. An interlayer insulation layer (not shown) is disposed between the m X-directional wirings 82 and the n Y-directional wirings 83 to electrically isolate them from each other, the m X-directional wirings and n Y-directional wirings forming a matrix. (m and n are integers.)

[0078]

The interlayer insulation layer (not shown) is typically made of SiO_2 and formed on the entire surface or part of the surface of the X-directional wiring 82 formed insulating substrate 1 to show a desired contour by means of vacuum deposition, printing or sputtering. The thickness, material and manufacturing method of the interlayer insulation layer are so selected as to make it withstand any potential difference between an X-directional wiring 82 and a

Y-directional wiring 83 at the crossing thereof. Each of the X-directional wirings 82 and the Y-directional wirings 83 is drawn out to form an external terminal.

[0079]

The oppositely arranged electrodes (not shown) of each of the surface conduction electron-emitting devices 84 are connected to the related one of the m X-directional wirings 82 (DX1, DX2, ..., DXm and the related one of the n Y-directional wirings 83 (DY1, DY2, ..., DYn) by respective connecting wires 85 which are made of a conductive metal and formed by vacuum deposition, printing or sputtering.

[0080]

The electroconductive metal material of the device electrodes and that of the connecting wires 85 extending from the m X-directional wirings 82 and the n Y-directional wirings 83 may be same or contain common elements as ingredients. The material is appropriately selected from metals such as Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu and Pd and their alloys, printable conducting materials made of a metal or a metal oxide selected from Pd, Ag, RuO_2, Pd-Ag and glass, transparent conducting materials such as In_2O_3-SnO_2 and semiconductor materials such as poly-silicon. The surface conduction electron-emitting devices may be arranged directly on the substrate 1 or on the interlayer insulation layer (not shown).

[0081]

The X-directional wirings 82 are electrically

connected to a scan signal generating means (not shown) for applying a scan signal to a selected row of surface conduction electron-emitting devices 84 and scanning the selected row according to an input signal.

[0082]

On the other hand, the Y-directional wirings 83 are electrically connected to a modulation signal generating means (not shown) for applying a modulation signal to a selected column of surface conduction electron-emitting devices 84 and modulating the selected column according to an input signal.

[0083]

Note that the drive signal to be applied to each surface conduction electron-emitting device is expressed as the voltage difference of the scan signal and the modulation signal applied to the device.

[0084]

Now, an image-forming apparatus according to the invention and comprising an electron source as described above will be described by referring to Fig. 9 and Fig. 10. This apparatus may be a display apparatus. Fig. 9 illustrates the basic configuration of the display panel of the image-forming apparatus, and Fig. 10 shows a fluorescent film.

[0085]

In Fig. 9, the apparatus comprises an electron source substrate 1 of the above described type, a rear plate

91 rigidly holding the electron source substrate 1, a face plate 96 produced by laying a fluorescent film 94 and a metal back 95 on the inner surface of a glass substrate 93 and a support frame 92. An enclosure 98 is formed for the apparatus as frit glass is applied to said rear plate 91, said support frame 92 and said face plate 96, which are subsequently baked to 400 to 500°C in the atmosphere or in nitrogen and bonded together.

[0086]

In Fig. 9, reference numeral 84 denotes the electron-emitting region in Fig. 1 and reference numerals 82 and 83 respectively denotes the X-directional wiring and the Y-directional wiring connected to the respective device electrodes of each electron-emitting device. Further, wiring connected to these device electrodes may sometimes referred to as a device electrode when the device electrode and the wiring material are the same material.

[0087]

While the enclosure 98 is formed of the face plate 96, the support frame 92 and the rear plate 91 in the above described embodiment, the rear plate 91 may be omitted if the substrate 1 is strong enough by itself. If such is the case, an independent rear plate 91 may not be required and the substrate 1 may be directly bonded to the support frame 92 so that the enclosure 98 is constituted of a face plate 96, a support frame 92 and a substrate 1.

[0088]

Fig. 10 schematically illustrates a fluorescent film. While the fluorescent film 94 comprises only fluorescent bodies if the display panel is used for showing black and white pictures, it needs to comprises for displaying color pictures black conductive members 101 and fluorescent bodies 102, of which the former are referred to as black stripes or members of a black matrix depending on the arrangement of the fluorescent bodies. Black stripes or members of a black matrix are arranged for a color display panel so that the fluorescent bodies 102 of three different primary colors are made less discriminable and the adverse effect of reducing the contrast of displayed images of external light is weakened by blackening the surrounding areas. While graphite is normally used as a principal ingredient of the black stripes, other conductive material having low light transmissivity and reflectivity may alternatively be used.

[0089]

A precipitation or printing technique is suitably be used for applying a fluorescent material on the glass substrate 93 regardless of black and white or color display.

[0090]

An ordinary metal back 95 is arranged on the inner surface of the fluorescent film 94. The metal back 95 is provided in order to enhance the luminance of the display panel by causing the rays of light emitted from the

fluorescent bodies and directed to the inside of the enclosure to turn back toward the face plate 96, to use it as an electrode for applying an accelerating voltage to electron beams and to protect the fluorescent bodies against damages that may be caused when negative ions generated inside the enclosure collide with them. It is prepared by smoothing the inner surface of the fluorescent film 94 (in an operation normally called "filming") and forming an Al film thereon by vacuum deposition after forming the fluorescent film 94.

[0091]

A transparent electrode (not shown) may be formed on the face plate 96 facing the outer surface of the fluorescent film 94 in order to raise the conductivity of the fluorescent film 94.

[0092]

Care should be taken to accurately align each set of color fluorescent bodies and an electron-emitting device, if a color display is involved, before the above listed components of the enclosure are bonded together.

[0093]

The enclosure 98 is then evacuated by way of an exhaust pipe (not shown) to a degree of vacuum of approximately 10^{-6} torr and the enclosure 91 is hermetically sealed.

[0094]

After evacuating the enclosure in a vacuum of about

10^{-6} torr by way of an exhaust pipe (not shown) for example, in a usual vacuum chamber such as a rotary pump or turbo pump, a voltage is applied to the device electrodes of each device by way of external terminals Dx1 through Dxm and Dy1 through Dyn for a forming operation to produce an electron-emitting region 3 of the electron-emitting device. Most preferably, a baking operation is carried out at 80°C to 200°C for 3 to 15 hours, during which the vacuum system in the enclosure is switched to an ultra-high vacuum system comprising an ion pump or the like. The switch to an ultra-high vacuum system and the baking operation are intended to ensure the surface conduction electron-emitting device a satisfactorily monotonically increasing characteristic (MI characteristic) for both the device current If and the emission current Ie and, therefore, this objective may be achieved by some other means under different conditions. A getter operation may be carried out after sealing the enclosure 98 in order to maintain that degree of vacuum in it. A getter operation is an operation of heating a getter (not shown) arranged at a given location in the enclosure 98 immediately before of after sealing the enclosure 98 by resistance heating or high frequency heating to produce a vapor deposition film. A getter normally contains Ba as a principle ingredient and the formed vapor deposition film can typically maintain the inside of the enclosure to a degree of 1×10^{-5} to 10^{-7} torr by its adsorption effect.

[0095]

An image-forming apparatus according to the invention thus produced is operated by applying a voltage to each electron-emitting device by way of the external terminal Dox1 through Doxm and Doy1 through Doyn to cause the electron-emitting devices to emit electrons. Meanwhile, a voltage higher than several kV is applied to the metal back 95 or the transparent electrode (not shown) by way of high voltage terminal Hv to accelerate electron beams and cause them to collide with the fluorescent film 94, which by turn is energized to emit light to display intended images.

[0096]

While the configuration of a display panel to be suitable used for an image-forming apparatus according to the invention is outlined above in terms of indispensable components thereof, the materials of the components are not limited to those described above and other materials may appropriately be used depending on the application of the apparatus.

[0097]

[Examples]

Now, the present invention will be described in greater detail by way of examples.

[0098]

(Example 1)

The surface conduction electron-emitting device

according to the present invention had a basic configuration same as the one illustrated in the plan view of Fig. 1(a) and the sectional view of Fig. 1(b).

[0099]

Four identical devices were formed on a substrate 1. Note that the reference numeral in Fig. 11 denote respective components identical with those of Figs. 1.

[0100]

The method of manufacturing the surface conduction electron-emitting devices was basically same as the one illustrated in Fig. 2. The basic configuration of the device specimen and the method for manufacturing the same will be described below by referring to Figs. 1 and 2.

[0101]

Referring to Fig. 1, the device comprised a substrate 1, a pair of device electrodes 5 and 6, a thin film 4 including an electron-emitting region 3.

[0102]

The method used for manufacturing the devices will be described below in terms of an experiment conducted, referring to Figs. 1 and 2.

[0103]

Step a:

On thoroughly cleaned soda lime glass plate, a silicon oxide film was formed thereon to a thickness of 0.5 microns by sputtering to produce a substrate 1, on which a pattern of photoresist (RD-2000N-41: available from Hitachi

Chemical Co., Ltd.) was formed for electrode 5 and a gap G separating the electrodes and then Ti and Ni were sequentially deposited thereon respectively to thicknesses of 50 Å and 1,000 Å by vacuum deposition. The photoresist pattern was dissolved by an organic solvent and the Ni/Ti deposit film was treated by using a lift-off technique to produce a pair of device electrodes 5 and 6 having a width W1 of 300 microns and separated from each other by a distance G of 3 microns (Fig. 2(a)).

[0104]

Step b:

A Cr film was formed by using a mask having opening at the gap between device electrodes or the neighboring area thereof to a film thickness of 1,000 Å by vacuum deposition, which was then subjected to a patterning operation. Thereafter, organic Pd (ccp4230: available from Okuno Pharmaceutical Co., Ltd.) was applied to the Cr film by means of a spinner, while rotating the film, and baked at 300°C for 10 minutes to produce a thin film 2 for forming an electron-emitting region, which was made of fine particles containing Pd as a principal ingredient and had a film thickness of 100 angstroms and an electric resistance per unit area of 2×10^4 Ω/□. Note that the term "a fine particle film" as used herein refers to a thin film constituted of a large number of fine particles that may be loosely dispersed, tightly arranged or mutually and randomly overlapping (to form an island structure under certain

conditions). The diameter of fine particles to be used for the purpose of the present invention is that of recognizable fine particles arranged in any of the above described states.

[0105]

Step c:

The Cr film and the baked thin film 2 for forming an electron-emitting region were etched by using an acidic etchant to produce a desired pattern. Now, a pair of device electrodes 5 and 6 and a thin film 2 for forming an electron-emitting region were produced on the substrate 1 (Fig. 2(b)).

[0106]

Step d:

Then, a gauging system as illustrated in Fig. 3 was set in position and the inside was evacuated by means of an exhaust pump to a degree of vacuum of 2×10^{-5} torr. Subsequently, a voltage was applied to the device electrodes 5, 6 in three devices for electrically energizing the device (electric forming process) by the power source 31 provided there for applying a device voltage Vf to the device. Fig. 4(b) shows the waveform of the voltage used for the electric forming process.

[0107]

In Fig. 4(b), T1 and T2 respectively denote the pulse width and the pulse interval of the applied pulse voltage, which were respectively 1 millisecond and 10

milliseconds for the experiment. The wave height of a rectangular waveform (the peak voltage for the forming operation) of the applied pulse voltage was increased stepwise with a step of 0.1 V. During the forming operation, a resistance measuring pulse voltage of 0.1 V was inserted during each T2 to determine the current resistance of the device. The forming operation was terminated when the gauge for the resistance measuring pulse voltages showed a reading of resistance of approximately 1 M ohms, at the same time, application of voltage to the devices was terminated. The forming voltage Vform was 5.1 V and 5.0 V.

[0108]

Step e:

Two pairs of devices that had undergone a forming process were subjected to an activation process, where voltages having a rectangular waveform (Fig. 4(b)) with wave heights of 4 V and 14 V were respectively applied to each pair of devices. Hereinafter, the specimens subjected to a low resistance activation process with 4 V will be referred to as devices A, whereas the specimens subjected to a high resistance activation process with 14 V will be referred to as devices B.

[0109]

In the activation process, the above described pulse voltages were applied to the device electrodes of the respective devices in the gauging system of Fig. 3, while observing the device current If and the emission current Ie.

The degree of vacuum in the gauging system of Fig. 3 was 1.5×10^{-5} torr. The activation process continued for 30 minutes for each device.

[0110]

An electron-emitting region 3 was then formed on each of the devices to produce a complete electron-emitting device.

[0111]

In an attempt to see the properties and the profile of the surface conduction electron-emitting devices prepared through the preceding steps, a device A and a device B were observed for electron-emitting performance, using a gauging system as illustrated in Fig. 3. The remaining pair of devices were observed through a microscope.

[0112]

In the above observation, the distance between the anode and the electron-emitting device was 4 mm and the potential of the anode was 1 kV, while the degree of vacuum in the vacuum chamber of the system was held to 1×10^{-6} torr throughput the gauging operation. A device voltage of 14 V was applied between the device electrodes 5, 6 of each of the devices A and B to see the device current If and the emission current Ie under that condition. A device current If of approximately 10 mA began to flow through the device A immediately after the start of measurement but the current gradually declined and the emission current Ie also showed a decline. On the other hand, a steady flow was observed

for both the device current If and the emission current Ie in the device B from the start of measurement. A device current If of 2.0 mA and an emission current Ie of 1.0 μA were observed for a device voltage of 14 V to provides an electron emission efficiency η = Ie/If x 100 (%) of 0.05%. Thus, it will be seen that the device A showed a large and unstable device current If in the initial stages of measurement whereas the device B proved to be stable and have an excellent electron emission efficiency η from the very start of measurement.

[0113]

When the degree of vacuum in the activation process was held to be 1.5 x 10^{-5} torr for a device B and the device current If and the emission current Ie were observed, sweeping the device with a triangular pulse voltage with a frequency of approximately 0.005 Hz, the device current If was such as indicated by the broken line in Fig. 12. As seen from Fig. 12, the device current If monotonically increased to approximately 5 V and then showed a voltage-controlled-negative-resistance above the 5 V level. The device voltage at which the device current If reaches a peak is referred to VP which was 5 V for the specimen. It should be noted that the device current If was reduced to a fraction of the maximum device current or approximately 1 mA beyond 10 V. When observed through a microscope, the devices A and B showed profiles similar to those illustrated in Figs. 6(a) and 6(b) respectively. From Fig. 6(a), it is found

that the device A carried a coat formed in the transformed area 3 of the thin film between the device electrodes that had been transformed, while in case of the device B, from Fig. 6(b) it is found that a coat was formed mainly on the high potential side from part of the transformed area 3 along the direction along which a voltage was applied to the device in the activation process. When observed through an FESEM (secondary electron microscope) having large magnifying power, it was found that the coat existed around part of the fine metal particles and in part of the inter-particle space of the device.

[0114]

When observed through a TEM (transmission electron microscope) or a Raman microscope, it was found that the carbon coat was made of graphite and amorphous carbon.

[0115]

From these observations, it may be safe to say that carbon was produced in the area of the thin film of the device A that had been transformed by the forming process as the area was activated by a voltage below the voltage level of Vp required for voltage-controlled-negative-resistance as described above so that the carbon coat formed between the high and low potential sides of the transformed area of the thin film provided a current path for the device current through which a large device current was allowed to flow at a rate several times greater than the device current of the device B from the very beginning.

[0116]

Contrary to this, the device B was activated by a voltage above the voltage level of Vp required for voltage-controlled-negative-resistance in a high resistance activation process so that, if a carbon coat had been formed, it may have been electrically disrupted to ensure a stable device current to flow from the beginning.

[0117]

Thus, an electron-emitting device having a device current If and a emission current Ie that are stable and capable of efficiently emitting electron can be prepared by a high resistance activation process.

[0118]

(Example 2)

In this example, a large number of surface conduction electron-emitting devices were arranged to a simple matrix arrangement to produce an image-forming apparatus.

[0119]

Fig. 13 is a partial plan view of the electron source. Fig. 14 is a schematic sectional side view of Fig. 13 taken along line A-A'. Note that reference symbols in Figs. 13, 14, 15 and 16 respectively denote identical items throughout the drawings. Thus, reference numerals 81, 82 and 83 respectively denote a substrate, an X-directional wiring corresponding to an external terminal Dxm (also referred to as a lower wiring) and a Y-direction wiring

corresponding to an external terminal Dyn (also referred to as an upper wiring), whereas reference numeral 4 denotes a thin film including an electron-emitting region, reference numerals 5 and 6 denote a pair of device electrodes and reference numerals 141 and 142 respectively denotes an interlayer insulation layer and a contact hole for connecting a device electrode 5 and a lower wiring 82.

[0120]

Now, the method of manufacturing will be described below in terms of an experiment conducted, referring to Figs. 15 and 16.

[0121]

Step a:

On a thoroughly cleaned soda lime glass plate, a silicon oxide film was formed thereon to a thickness of 0.5 microns by sputtering to produce a substrate 1, on which a photoresist (AZ1370: available from Hoechst Corporation) was formed by means of a spinner, while rotating the film, and baked. Thereafter, a photo-mask image was exposed to light and developed to produce a resist pattern for the lower wirings 82 and then the deposited Au/Cu film was wet-etched to produce lower wires 82 having a desired profile (Fig. 15(a)).

[0122]

Step b:

A silicon oxide film was formed as an interlayer insulation layer 141 to a thickness of 1.0 micron by RF

sputtering (Fig. 15(b)).

[0123]

Step c:

A photoresist pattern was prepared for producing a contact hole 142 in the silicon oxide film deposited in Step b, which contact hole 142 was then actually formed by etching the interlayer insulation layer 141, using the photoresist pattern for a mask. RIE (Reactive Ion Etching) using CF_4 and H_2 gas was employed for the etching operation (Fig. 15(c)).

[0124]

Step d:

Thereafter, a pattern of photoresist (RD-2000N: available from Hitachi Chemical Co., Ltd.) was formed for a pair of device electrode 5 and a gap G separating the electrodes and then Ti and Ni were sequentially deposited thereon respectively to thicknesses of 50 Å and 1,000 Å by vacuum deposition. The photoresist pattern was dissolved by an organic solvent and the Ni/Ti deposit film was treated by using a lift-off technique to produce a pair of device electrodes 5 and 6 having a width W1 of 300 microns and separated from each other by a device electrode distance G of 3 microns (Fig. 15(d)).

[0125]

Step e:

After forming a photoresist pattern on the device electrodes 5, 6 for upper wirings 83, Ti and Au were

sequentially deposited by vacuum deposition to respective thicknesses of 50 Å and 5,000 Å and then unnecessary areas were removed by means of the lift-off technique to produce upper wirings 84 having a desired profile (Fig. 16(e)).

[0126]

Step f:

A Cr film 151 is formed to a film thickness of 1,000 Å by vacuum deposition, which was then subjected to a patterning operation. Thereafter, organic Pd (ccp4230: available from Okuno Pharmaceutical Co., Ltd.) was applied to the Cr film by means of a spinner, while rotating the film, and baked at 300°C for 10 minutes to produce a thin film 2 for forming an electron-emitting region, which was made of fine particles containing Pd as a principal ingredient and had a film thickness of 100 Å and an electric resistance per unit area of 5×10^4 Ω/□. Note that the term "a fine particle film" as used herein refers to a thin film constituted of a large number of fine particles that may be loosely dispersed, tightly arranged or mutually and randomly overlapping (to form an island structure under certain conditions). The diameter of fine particles to be used for the purpose of the present invention is that of recognizable fine particles arranged in any of the above described states (Fig. 16(f)).

[0127]

Step g:

The Cr film 151 and the baked thin film 2 for forming

an electron-emitting region were etched by using an acidic etchant to produce a desired pattern (Fig. 16(g)).

[0128]

Step h:

Then, a pattern for applying photoresist to the entire surface area except the contact hole 142 was prepared and Ti and Au were sequentially deposited by vacuum deposition to respective thicknesses of 50 Å and 5,000 Å. Any unnecessary areas were removed by means of the lift-off technique to consequently bury the contact hole 142 (Fig. 14(h)).

[0129]

Now, a lower wirings 82, an interlayer insulation layer 141, upper wirings 83, a pair of device electrodes 5 and 6 and a thin film 2 for forming an electron-emitting region were produced on the substrate 1.

[0130]

In an experiment, an electron source and a display apparatus were produced by using an electron source prepared in the above experiment. This apparatus will be described by referring to Figs. 9 and 10.

[0131]

A substrate 1 carrying thereon a large number of surface conduction electron-emitting devices prepared according to the above described process was rigidly fitted to a rear plate 91 and thereafter a face plate (prepared by forming a fluorescent film 94 and a metal back 95 on a glass

substrate 93) was arranged 5 mm above the substrate 1 by interposing a support frame 92 therebetween. Frit glass was applied to junction areas of the face plate 96, the support frame 92 and the rear plate 91, which were then baked at 400°C for 10 minutes in the atmosphere and bonded together. The substrate 1 was also firmly bonded to the rear plate 91 by means of frit glass.

[0132]

In Fig. 9, reference numeral 84 denotes electron-emitting devices and numerals 82 and 83 respectively denotes X-directional wirings and Y-directional wirings.

[0133]

While the fluorescent film 94 may be soleley made of fluorescent bodies if the image-forming apparatus is for black and white pictures, firstly black stripes were arranged and then the gaps separating the black stripes were filled with respective fluorescent bodies for primary colors to produce a fluorescent film 94 in this experiment (Fig. 10(a)). The black stripes were made of a popular material containing graphite as a principal ingredient. The fluorescent bodies were applied to the glass substrate 93 by using a slurry method.

[0134]

A metal back 95 is normally arranged on the inner surface of the fluorescent film 94. In this experiment, a metal back was prepared by producing an Al film by vacuum deposition on the inner surface of the fluorescent film

that had been smoothed in a so-called filming process.

[0135]

The face plate 96 may be additionally provided with transparent electrodes (not shown) arranged close to the outer surface of the fluorescent film 94 in order to improve the conductivity of the fluorescent film 94, no such electrodes were used in the experiment because the metal back proved to be sufficiently conductive.

[0136]

The fluorescent bodies were carefully aligned with the respective electron-emitting devices before the above described bonding operation.

[0137]

The prepared glass container was then evacuated by means of an exhaust pipe (not shown) and an exhaust pump to achieve a sufficient degree of vacuum inside the container. Thereafter, the thin films 2 of the electron-emitting devices 74 were subjected to an electric forming operation, where a voltage was applied to the device electrodes 5, 6 of the electron-emitting devices 84 by way of the external terminals Dox1 through Doxm and Doy1 through Doyn. The voltage used in the forming operation had a waveform same as the one shown in Fig. 4(b).

[0138]

In this experiment, T1 and T2 were respectively 1 millisecond and 10 milliseconds and the electric forming operation was carried out in vacuum of a degree of

approximately 1 x 10^{-5} torr.

[0139]

Dispersed fine particles containing palladium as a principal ingredient were observed in the electron-emitting region 3 that had been produced in the above process. The fine particles had an average particle size of 30 angstroms.

[0140]

Thereafter, the devices were subjected to a high resistance activation process, where a voltage having a rectangular waveform same as that of the voltage used in the forming operation and a wave height of 14 V was applied to each device, observing the device current If and the emission current Ie in vacuum of a degree of 2 x 10^{-5} torr.

[0141]

Finished electron-emitting devices 84 having an electron-emitting region 3 were produced after the forming and activation processes.

[0142]

Subsequently, the enclosure was evacuated to a degree of vacuum of approximately 10^{-6} torr and then hermetically sealed by melting and closing the exhaust pipe (not shown) by means of a gas burner.

[0143]

Finally, the apparatus was subjected to a getter process using a high frequency heating technique in order to maintain the degree of vacuum in the apparatus after

the sealing operation.

[0144]

The electron-emitting devices of the above image-forming apparatus were then caused to emit electrons by applying a scan signal and a modulation signal from a signal generating means (not shown) through the external terminals Dx1 through Dxm and Dy1 through Dyn and the emitted electrons were accelerated by applying a high voltage of several kV of higher to the metal back 95 via the high voltage terminal Hv so that they collides with the fluorescent film 99 until the latter was energized to emit light and produce an image.

[0145]

(Example 3)

Fig. 17 is a block diagram of the display apparatus comprising an electron source realized by arranging a number of surface conduction electron-emitting devices and a display panel and designed to display a variety of visual data as well as pictures of television transmission in accordance with input signals coming from different signal sources. Referring to Fig. 17, the apparatus comprises a display panel 17100, a display panel drive circuit 17101, a display controller 17102, a multiplexer 17103, a decoder 17104, an input/output interface circuit 17105, a CPU 17106, an image generation circuit 17107, image memory interface circuits 17108, 17109 and 17110, an image input interface circuit 17111, TV signal receiving circuits 17112 and 17113

and an input section 17114. (If the display apparatus is used for receiving television signals that are constituted by video and audio signals, circuits, speakers and other devices are required for receiving, separating, reproducing, processing and storing audio signals along with the circuits shown in the drawing. However, such circuits and devices are omitted here in view of the scope of the present invention.)

[0146]

Now, the components of the apparatus will be described, following the flow of image data therethrough.

[0147]

Firstly, the TV signal reception circuit 17113 is a circuit for receiving TV image signals transmitted via a wireless transmission system using electromagnetic waves and/or spatial optical telecommunication networks. The TV signal system to be used is not limited to a particular one and any system such as NTSC, PAL or SECAM may feasibly be used with it. It is particularly suited for TV signals involving a larger number of scanning lines (typically of a high definition TV system such as the MUSE system) because it can be used for a large display panel comprising a large number of pixels. The TV signals received by the TV signal reception circuit 17113 are forwarded to the decoder 17104.

[0148]

Secondly, the TV signal reception circuit 17112 is a circuit for receiving TV image signals transmitted via

a wired transmission system using coaxial cables and/or optical fibers. Like the TV signal reception circuit 17113, the TV signal system to be used is not limited to a particular one and the TV signals received by the circuit are forwarded to the decoder 17104.

[0149]

The image input interface circuit 17111 is a circuit for receiving image signals forwarded from an image input device such as a TV camera or an image pick-up scanner. It also forwards the received image signals to the decoder 17104.

[0150]

The image memory interface circuit 17110 is a circuit for retrieving image signals stored in a video tape recorder (hereinafter referred to as VTR) and the retrieved image signals are also forwarded to the decoder 17104.

[0151]

The image memory interface circuit 17109 is a circuit for retrieving image signals stored in a video disc and the retrieved image signals are also forwarded to the decoder 17104.

[0152]

The image memory interface circuit 17108 is a circuit for retrieving image signals stored in a device for storing still image data such as so-called still disc and the retrieved image signals are also forwarded to the decoder 17104. The input/output interface circuit 17105 is

a circuit for connecting the display apparatus and an external output signal source such as a computer, a computer network or a printer. It carries out input/output operations for image data and data on characters and graphics and, if appropriate, for control signals and numerical data between the CPU 17106 of the display apparatus and an external output signal source.

[0153]

The image generation circuit 17107 is a circuit for generating image data to be displayed on the display screen on the basis of the image data and the data on characters and graphics input from an external output signal source via the input/output interface circuit 17105 or those coming from the CPU 17106. The circuit comprises reloadable memories for storing image data and data on characters and graphics, read-only memories for storing image patterns corresponding given character codes, a processor for processing image data and other circuit components necessary for the generation of screen images.

[0154]

Image data generated by the circuit for display are sent to the decoder 17104 and, if appropriate, they may also be sent to an external circuit such as a computer network or a printer via the input/output interface circuit 17105.

[0155]

The CPU 17106 controls the display apparatus and

carries out the operation of generating, selecting and editing images to be displayed on the display screen.

[0156]

For example, the CPU sends control signals to the multiplexer 17103 and appropriately selects or combines signals for images to be displayed on the display screen. At the same time it generates control signals for the display panel controller 17102 and controls the operation of the display apparatus in terms of image display frequency, scanning method (e.g., interlaced scanning or non-interlaced scanning), the number of scanning lines per frame and so on.

[0157]

The CPU also sends out image data and data on characters and graphic directly to the image generation circuit 17107 and accesses external computers and memories via the input/output interface circuit 17105 to obtain external image data and data on characters and graphics. The CPU 17106 may additionally be so designed as to participate other operations of the display apparatus including the operation of generating and processing data like the CPU of a personal computer or a word processor. The CPU may also be connected to an external computer network via the input/output interface circuit 17105 to carry out computations and other operations, cooperating therewith.

[0158]

The input section 17114 is used for forwarding the instructions, programs and data given to it by the operator

to the CPU 17106. As a matter of fact, it may be selected from a variety of input devices such as keyboards, mice, joy sticks, bar code readers and voice recognition devices as well as any combinations thereof.

[0159]

The decoder 17104 is a circuit for converting various image signals input via said circuits 17107 through 17113 back into signals for three primary colors, luminance signals and I and Q signals. Preferably, the decoder 17104 comprises image memories as indicated by a dotted line in Fig. 17 for dealing with television signals such as those of the MUSE system that require image memories for signal conversion.

[0160]

The provision of image memories additionally facilitates the display of still images as well as such operations as thinning out, interpolating, enlarging, reducing, synthesizing and editing frames to be optionally carried out in cooperation with the image generation circuit 17107 and the CPU 17106.

[0161]

The multiplexer 17103 is used to appropriately select images to be displayed on the display screen according to control signals given by the CPU 17106. In other words, the multiplexer 17103 selects certain converted image signals coming from the decoder 17104 and sends them to the drive circuit 17101. It can also divide the display screen

in a plurality of frames to display different images simultaneously by switching from a set of image signals to a different set of image signals within the time period for displaying a single frame.

[0162]

The display panel controller 17102 is a circuit for controlling the operation of the drive circuit 17101 according to control signals transmitted from the CPU 17106.

[0163]

Among others, it operates to transmit signals to the drive circuit 17101 for controlling the sequence of operations of the power source (not shown) for driving the display panel in order to define the basic operation of the display panel. It also transmits signals to the drive circuit 17101 for controlling the image display frequency and the scanning method (e.g., interlaced scanning or non-interlaced scanning) in order to define the mode of driving the display panel.

[0164]

If appropriate, it also transmits signals to the drive circuit 17101 for controlling the quality of the images to be displayed on the display screen in terms of luminance, contrast, color tone and sharpness.

[0165]

The drive circuit 17101 is a circuit for generating drive signals to be applied to the display panel 17100.

It operates according to image signals coming from said multiplexer 17103 and control signals coming from the display panel controller 17102.

[0166]

A display apparatus according to the invention and having a configuration as described above and illustrated in Fig. 17 can display on the display panel 17100 various images given from a variety of image data sources. More specifically, image signals such as television image signals are converted back by the decoder 17104 and then selected by the multiplexer 17103 before sent to the drive circuit 17101. On the other hand, the display controller 17102 generates control signals for controlling the operation of the drive circuit 17101 according to the image signals for the images to be displayed on the display panel 17100. The drive circuit 17101 then applies drive signals to the display panel 17100 according to the image signals and the control signals. Thus, images are displayed on the display panel 17100. All the above described operations are controlled by the CPU 17106 in a coordinated manner.

[0167]

The above described display apparatus can not only select and display particular images out of a number of images given to it but also carry out various image processing operations including those for enlarging, reducing, rotating, emphasizing edges of, thinning out, interpolating, changing colors of and modifying the aspect

ratio of images and editing operations including those for synthesizing, erasing, connecting, replacing and inserting images as the image memories incorporated in the decoder 17104, the image generation circuit 17107 participates such operations. Although not described with respect to the above embodiment, it is possible to provide it with additional circuits exclusively dedicated to audio signal processing and editing operations.

[0168]

Thus, a display apparatus according to the invention and having a configuration as described above can have a wide variety of industrial and commercial applications because it can operate as a display apparatus for television broadcasting, as a terminal apparatus for video teleconferencing, as an editing apparatus for still and movie pictures, as a terminal apparatus for a computer system, as an OA apparatus such as a word processor, as a game machine and in many other ways.

[0169]

It may be needless to say that Fig. 17 shows only an example of possible configuration of a display apparatus comprising a display panel provided with an electron source prepared by arranging a number of surface conduction electron-emitting devices and the present invention is not limited thereto. For example, some of the circuit components of Fig. 17 may be omitted or additional components may be arranged there depending on the application. For

instance, if a display apparatus according to the invention is used for visual telephone, it may be appropriately made to comprise additional components such as a television camera, a microphone, lighting equipment and transmission/reception circuits including a modem.

[0170]

Since a diaplay apparatus according to the invention comprises a display panel that is provided with an electron source prepared by arranging a large number of surface conduction electron-emitting device and hence adaptable to reduction in the depth, the overall apparatus can be made very thin. Additionally, since a display panel comprising an electron source prepared by arranging a large number of surface conduction electron-emitting devices is adapted to have a large display screen with an enhanced luminance and provide a wide angle for viewing, it can offer really impressive scenes to the viewers with a sense of presence.

[0171]

[Effects of the Invention]

As described above, the present invention provides a method of manufacturing a surface conduction electron-emitting device comprising a pair of oppositely disposed device electrodes and a thin film including an electron-emitting region arranged on a substrate, wherein it comprises at least steps of forming a pair of electrodes, forming a thin film (including an electron-emitting region), conducting an electric forming process and conducting an activation

process so that the electron emission performance of the device that has hitherto been undeterminable in vacuum can be strictly controlled as the forming process and the activation process are conducted in two separate steps and a coat containing carbon in the form of graphite, amorphous carbon or a mixture thereof as a principal ingredient is formed on and around the electron-emitting region under a controlled manner.

[0172]

Preferably, the activation process comprises steps of forming a coat containing carbon as a principal ingredient on the thin film and applying a voltage exceeding the voltage-controlled-negative-resistance level to the pair of electrodes of the device in vacuum so that the coat containing carbon as a principal ingredient may be formed on the high voltage side from part of the electron-emitting region. With such an arrangement, the produced electron-emitting device can operate stably from the initial stages of operation with a low device current and a high efficiency.

[0173]

According to the invention, there is also provided an electron source designed to emit electrons in accordance to input signals and comprising a plurality of electron-emitting devices of the above described type on a substrate, wherein the electron-emitting devices are arranged in rows, each device being connected to wirings at opposite ends, and a modulation means is provided for them or, alternatively,

the pairs of device electrodes of the electron-emitting devices are respectively connected to m insulated X-directional wirings and n insulated Y-directional wirings, the electron-emitting devices being arranged in rows having a plurality of devices. With such an arrangement, an electron source according to the invention can be manufactured at low cost with a high yield. Additionally, an electron source according to the invention operates highly efficiently in an energy saving manner so that it alleviates the load imposed on the circuits that are peripheral to it.

[0174]

According to the invention, there is also provided an image-forming apparatus for forming images according to input signals, said apparatus comprising at least image-forming members and an electron source according to the invention. Such an apparatus can ensure efficient and stable emission of electrons to be carried out in a controlled manner. If, for example, the image-forming members are fluorescent members, the image-forming apparatus may make a flat color television set that can display high quality images with a low energy consumption level.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

Views showing the basic configuration of a surface conduction electron-emitting device according to the

invention.

[Fig. 2]

Views for illustrating a method of manufacturing a surface conduction electron-emitting device according to the invention.

[Fig. 3]

A view of a gauging system for determining the performance of a surface conduction electron-emitting device according to the invention.

[Fig. 4]

Graphs showing a voltage waveforms in the forming process according to the invention.

[Fig. 5]

A graph showing a dependency the device current and emission current to the time of activation process in a surface conduction electron-emitting device according to the invention.

[Fig. 6]

Views showing a transformation by activation process of a surface conduction electron-emitting device according to the invention.

[Fig. 7]

A graph showing a typical relationship among the emission current, device current and device voltage of a surface conduction electron-emitting device according to the invention.

[Fig. 8]

A view showing an electron source substrate according to the invention.

[Fig. 9]

A view showing a basic configuration of an image-forming apparatus according to the invention.

[Fig. 10]

A view showing a fluorescent film used for the image-forming apparatus in Fig. 10.

[Fig. 11]

A view showing a surface conduction electron-emitting device of Example 1 in the invention.

[Fig. 12]

A graph showing a performance of a surface conduction electron-emitting device of Example 1 in the invention.

[Fig. 13]

A partial view showing a configuration of an electron source of Example 2 in the invention.

[Fig. 14]

An A-A' sectional view of Fig. 13.

[Fig. 15]

A sectional view for illustrating a method of manufacturing an electron source of Example 2 in the invention.

[Fig. 16]

A sectional view for illustrating a method of

manufacturing an electron source of Example 2 in the invention.

[Fig. 17]

A view for illustrating a display apparatus of Example 3 in the invention.

[Fig. 18]

A view showing a conventional surface conduction electron-emitting device.

[Description of Reference Numerals and Symbols]

1 ... substrate

5, 6 ... device electrodes

4 ... thin film including an electron-emitting region

3 ... electron-emitting region

2 ... thin film for forming an electron-emitting region

84, 74 ... electron-emitting devices

82, 83 ... wirings

85 ... connecting wire

91 ... rear plate

92 ... support frame

98 ... enclosure

96 ... face plate

93 ... transparent substrate

94 ... fluorescent film

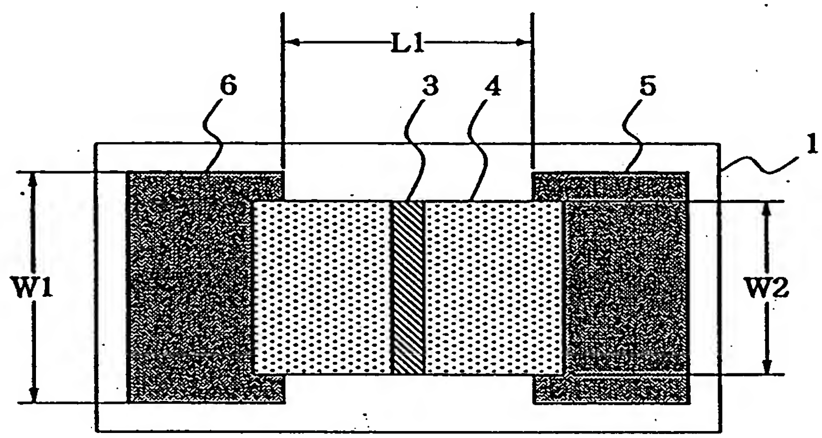
95 ... metal back

141 ... interlayer insulation layer

142 ... contact hole

Name of the Document
【書類名】　図面　Drawing

【図１】
[Fig. 1]



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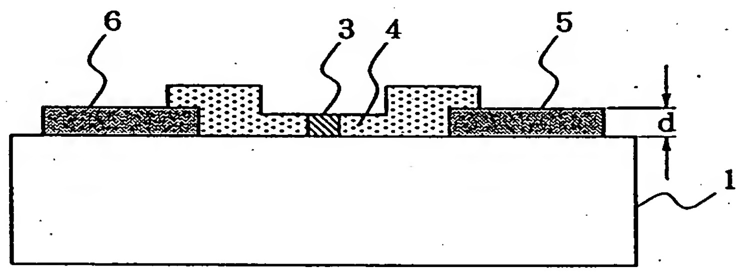
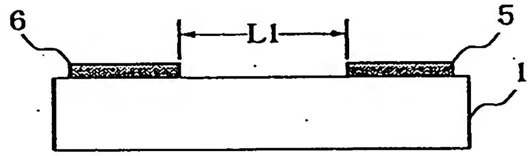


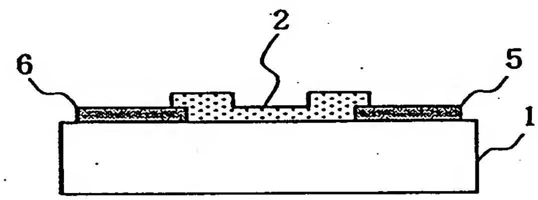
(b)

【図２】
[Fig. 2]

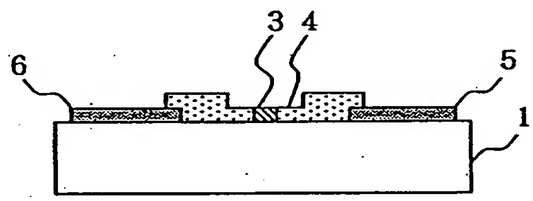
(a)



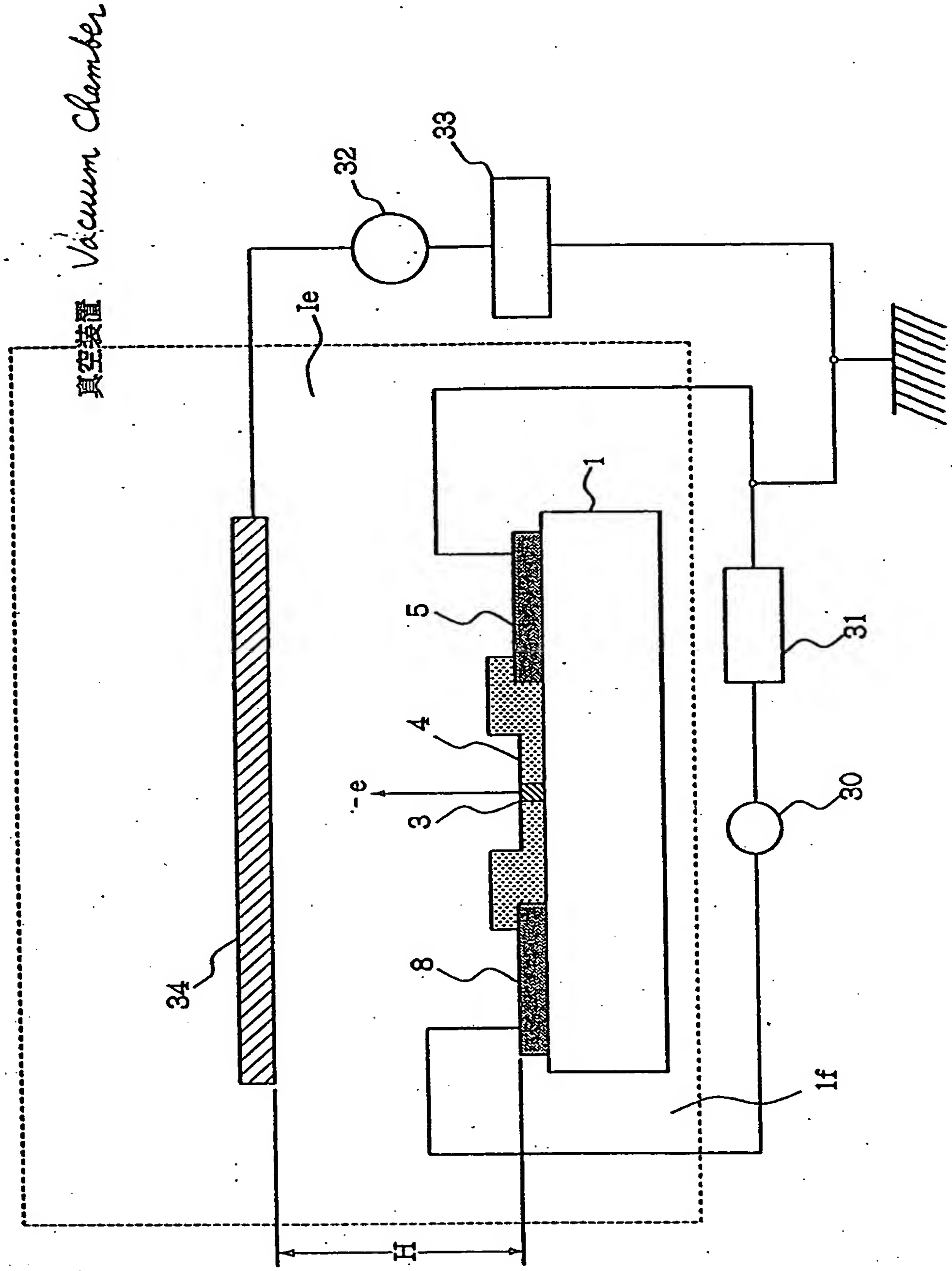
(b)



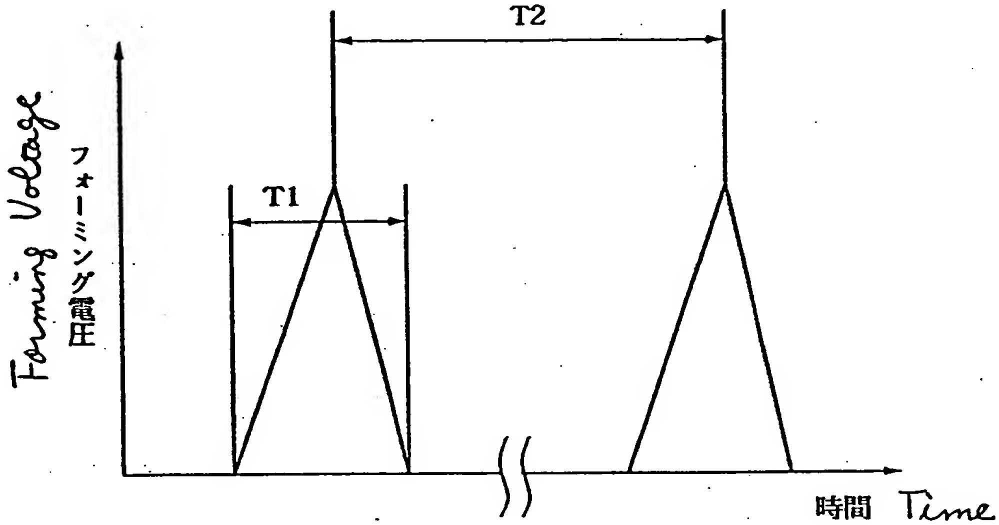
(c)



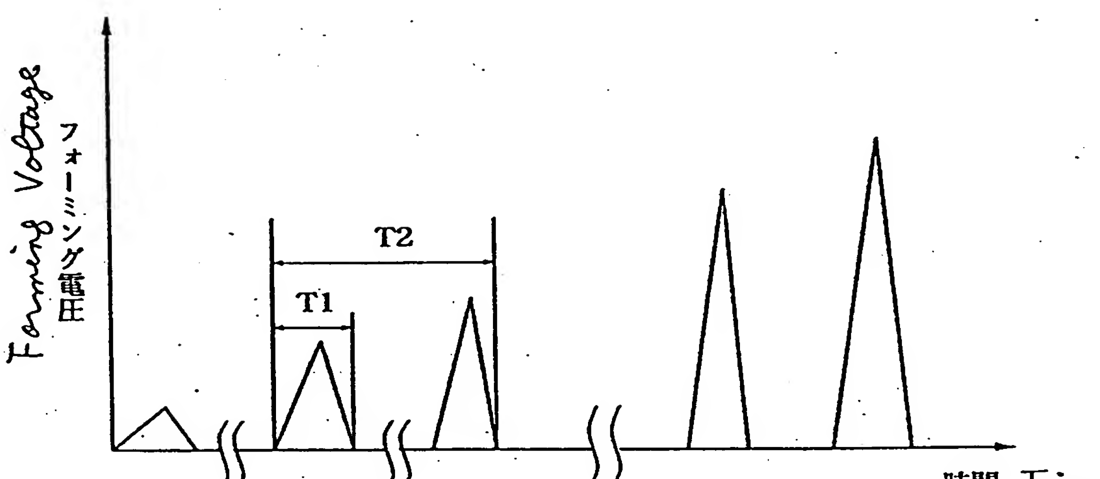
【図３】
[Fig. 3]



【図４】
[Fig.4]

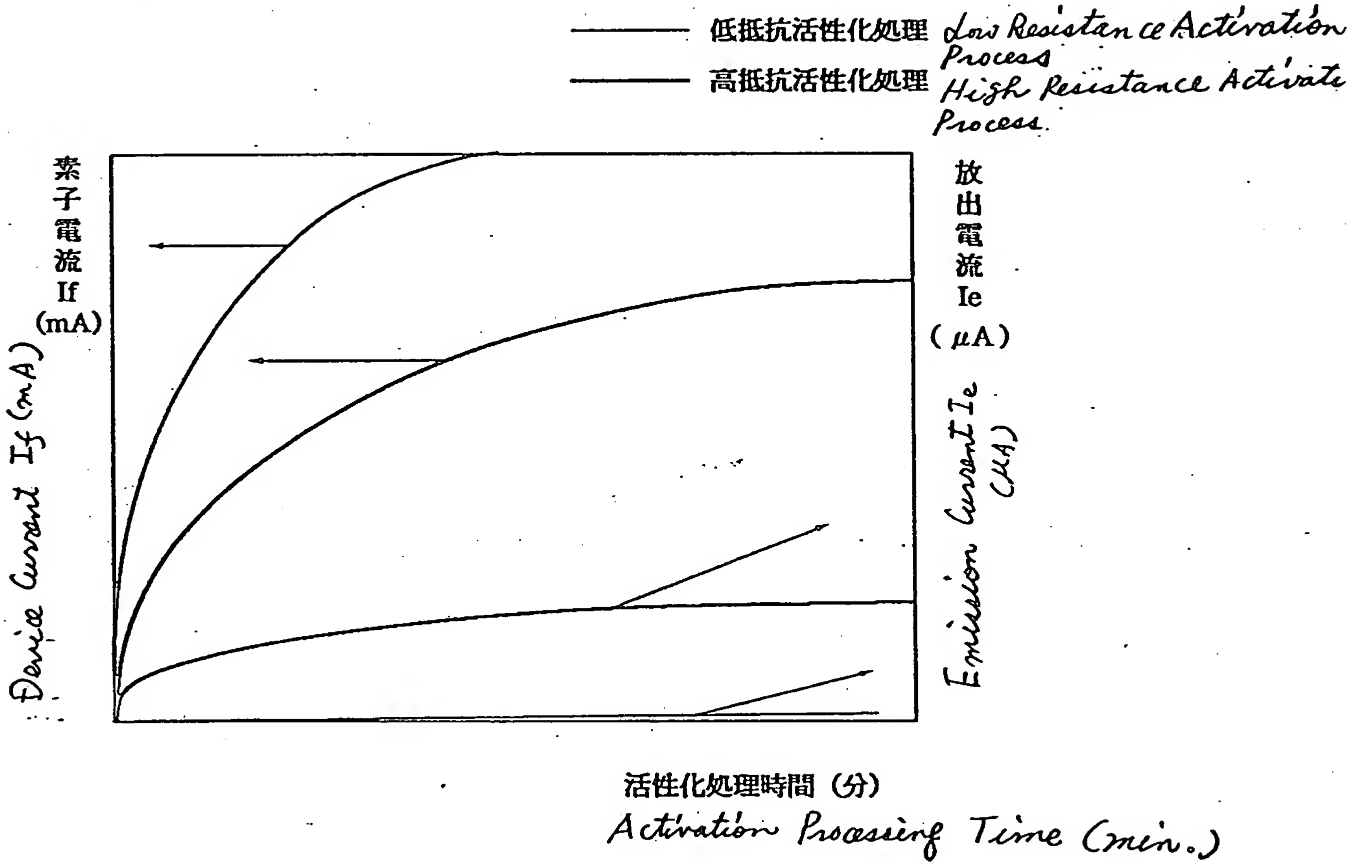

T2
T1
フォーミング電圧
Forming Voltage
時間 Time

(a)

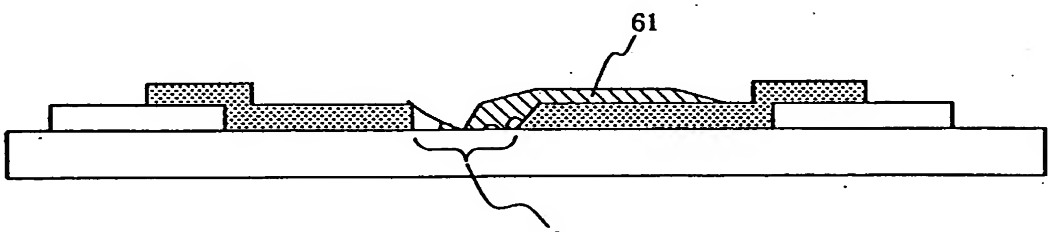

T2
T1
フォーミング電圧
Forming Voltage
時間 Time

(b)

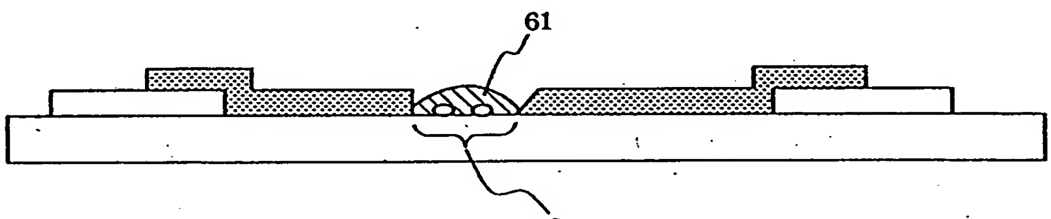
【図５】
[Fig. 5]


低抵抗活性化処理 Low Resistance Activation Process
高抵抗活性化処理 High Resistance Activate Process
素子電流 If (mA)
Device Current If (mA)
放出電流 Ie (μA)
Emission Current Ie (μA)
活性化処理時間（分）
Activation Processing Time (min.)

【図６】
[Fig. 6]

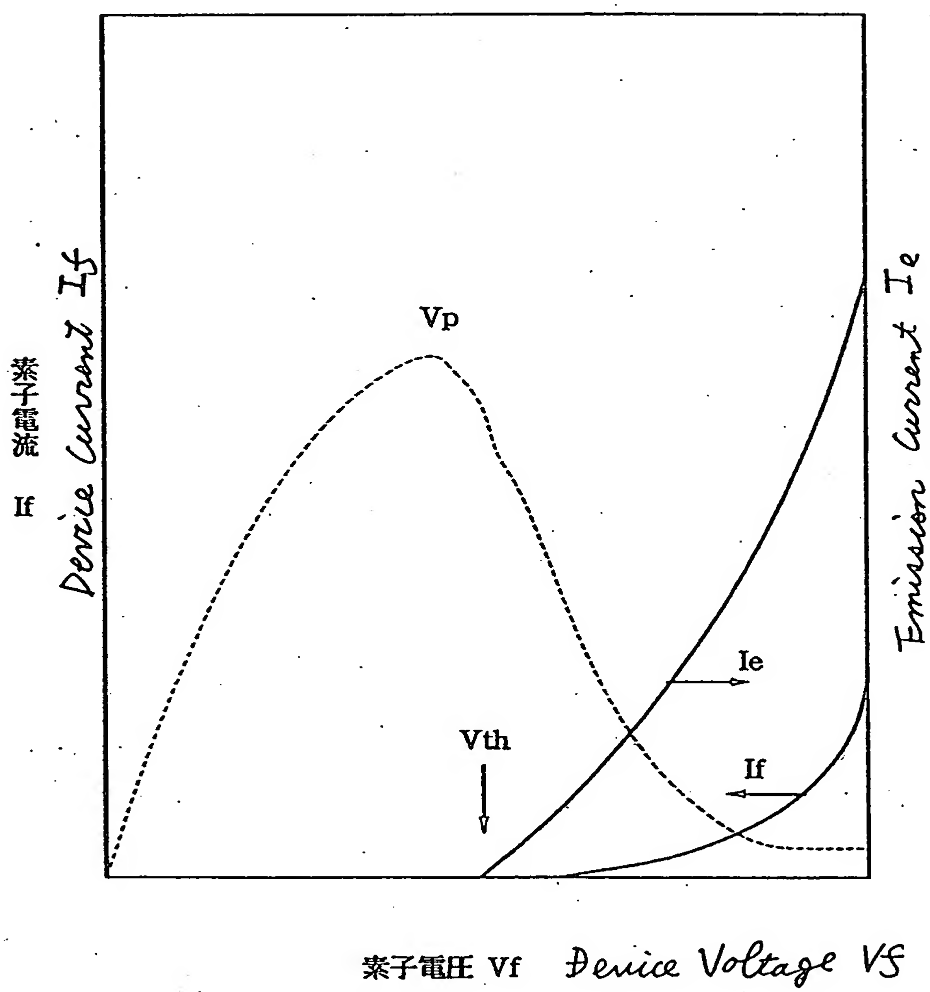


(a)

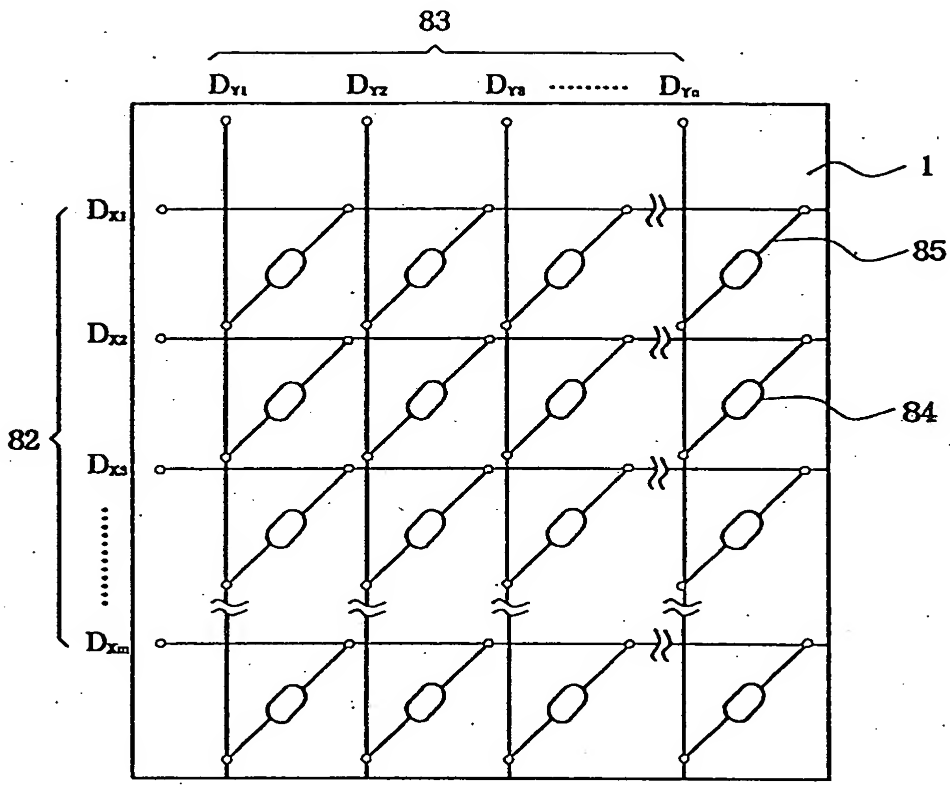


(b)

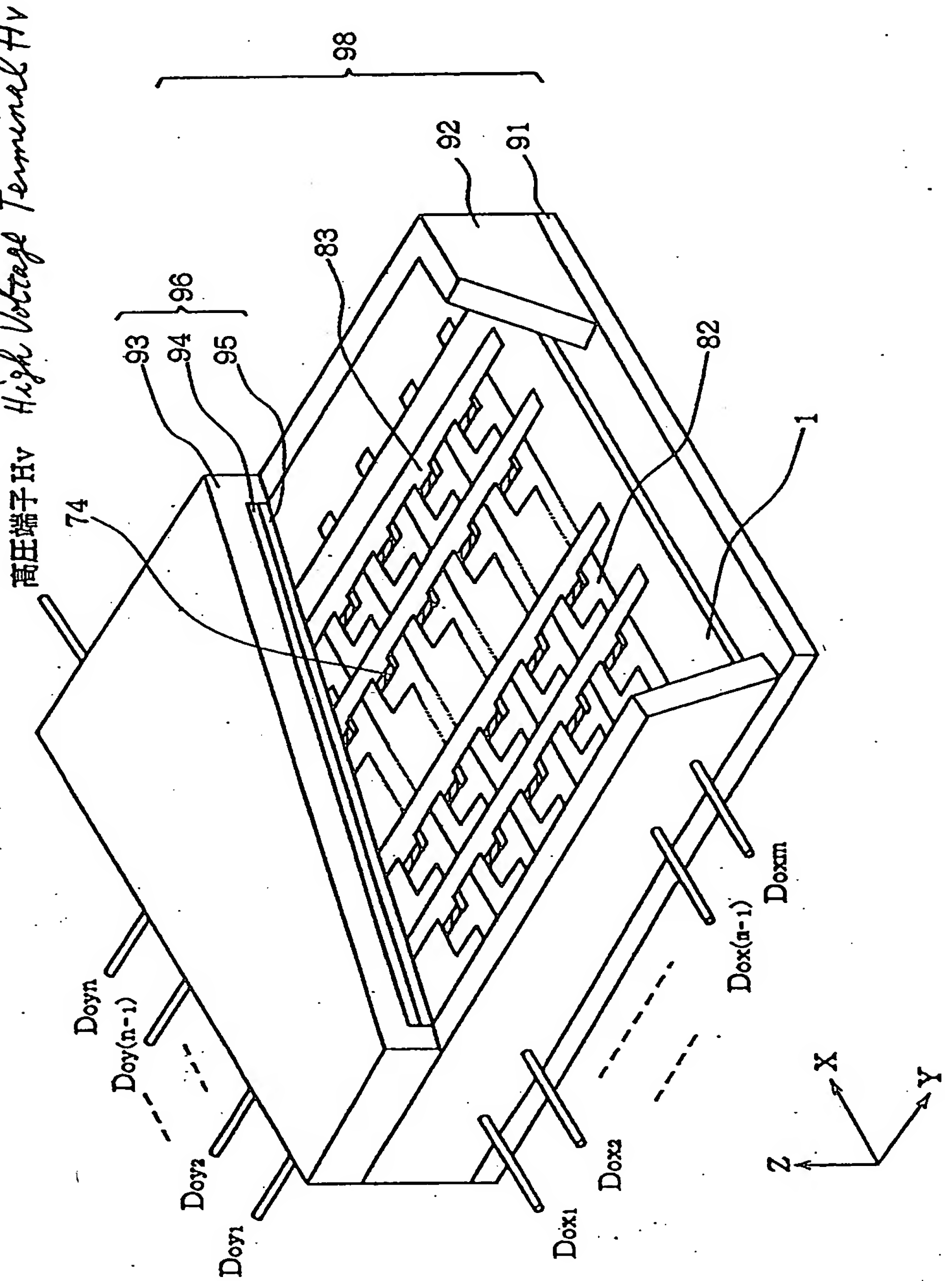
【図７】
[Fig.7]


素子電流 If
Device Current If
Vp
Vth
Ie
If
放出電流 Ie
Emission Current Ie
素子電圧 Vf
Device Voltage Vf

【図８】
[Fig.8]



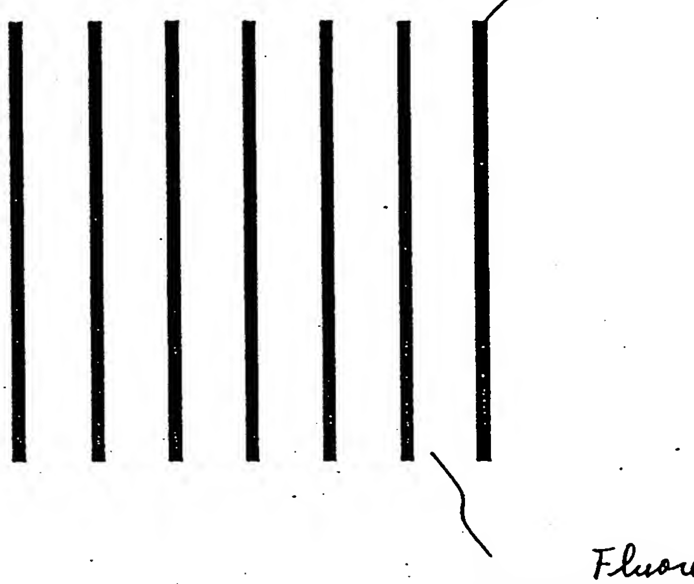
【図９】
[Fig. 9]


98
92
91
83
96
93
94
95
82
1
74
高圧端子Hv
High Voltage Terminal Hv
Doyn
Doy(n-1)
Doy2
Doy1
Dox1
Dox2
Dox(n-1)
Doxm
X
Y
Z

【図１０】
[Fig. 10]

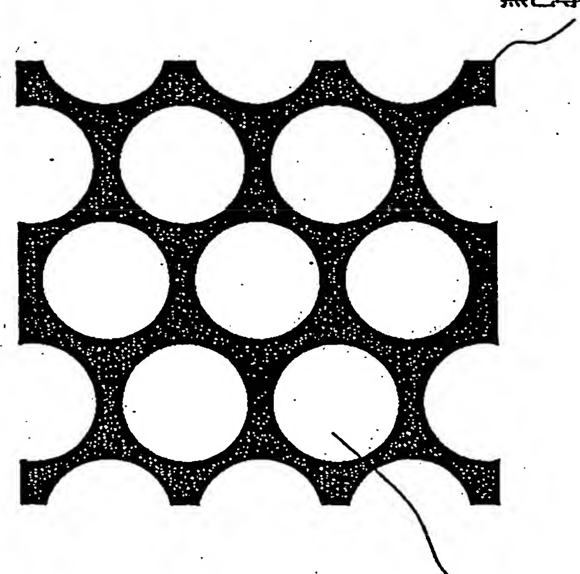
Stripe
ストライプ

(a)

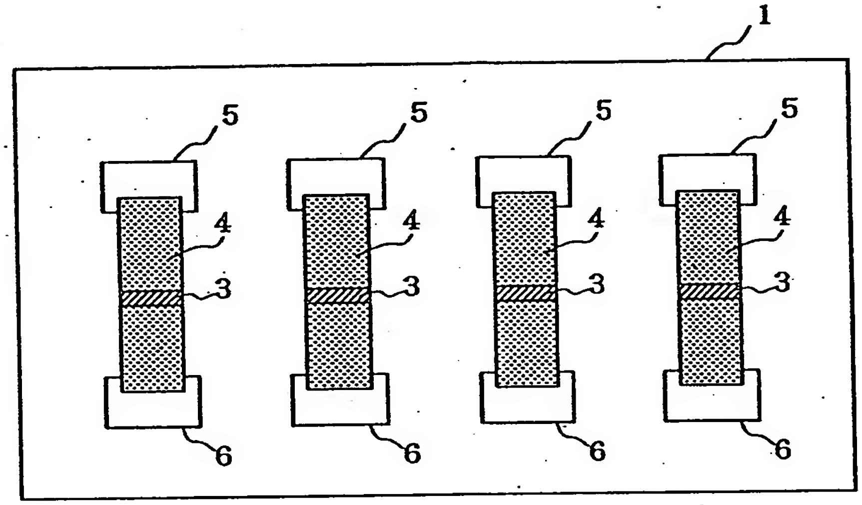


Matrix
マトリクス

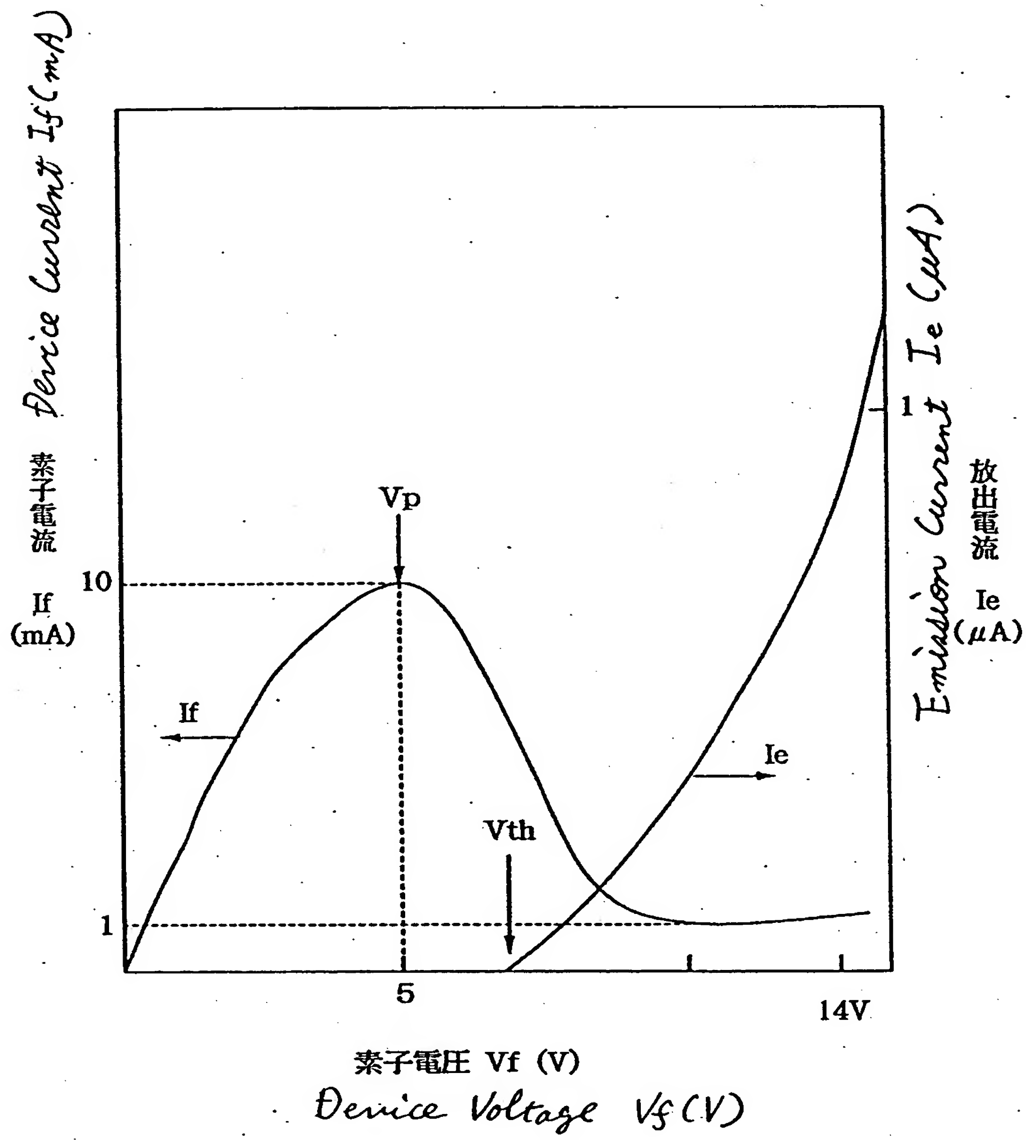
(b)



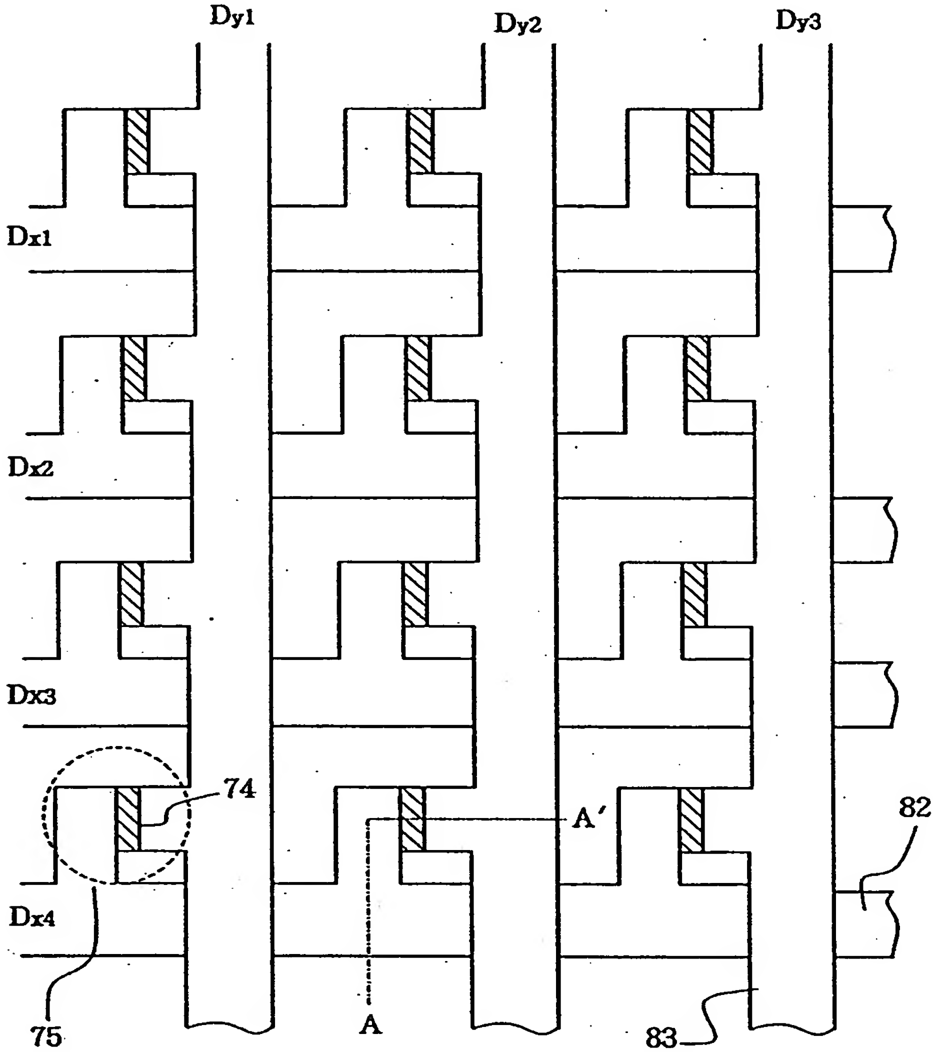
【図１１】
[Fig. 11]



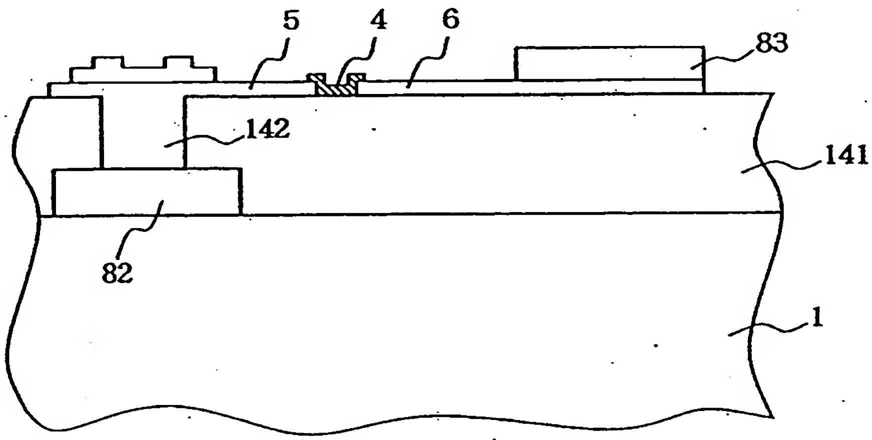
【図１２】
[Fig.12]


Device Current If (mA)
素子電流
If
(mA)
10
1
Vp
If
Vth
Ie
1
Emission Current Ie (μA)
放出電流
Ie
(μA)
5
14V
素子電圧 Vf (V)
Device Voltage Vf (V)

【図１３】
[Fig. 13]



【図１４】
[Fig.14]

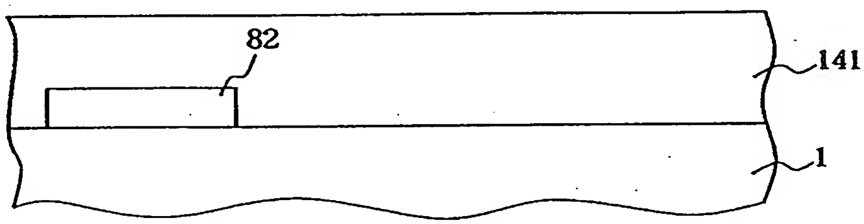


A－A' 断面図
A-A' Sectional View

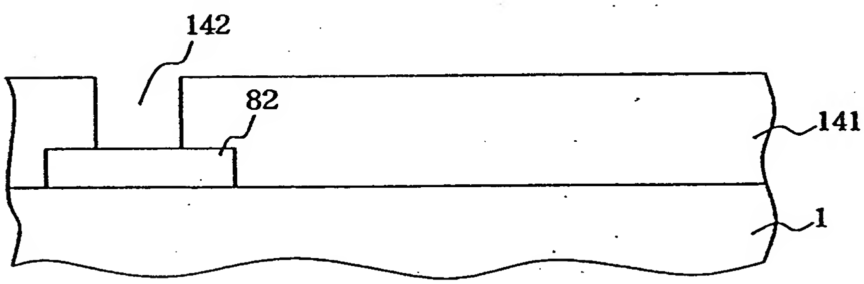
【図１５】
[Fig. 15]

(a)

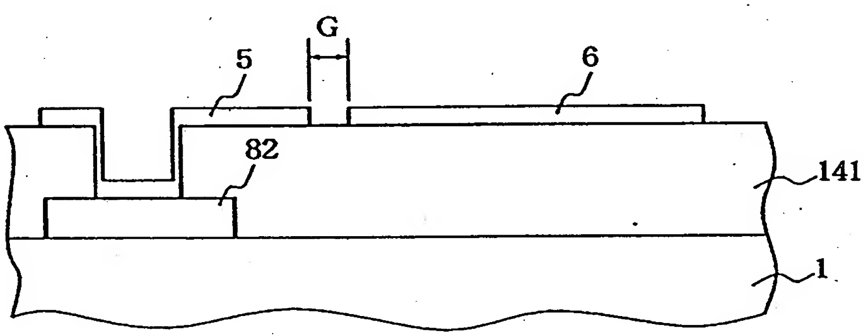
(b)



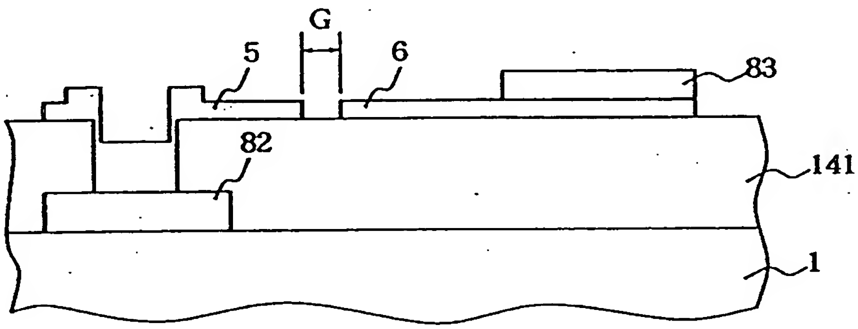
(c)



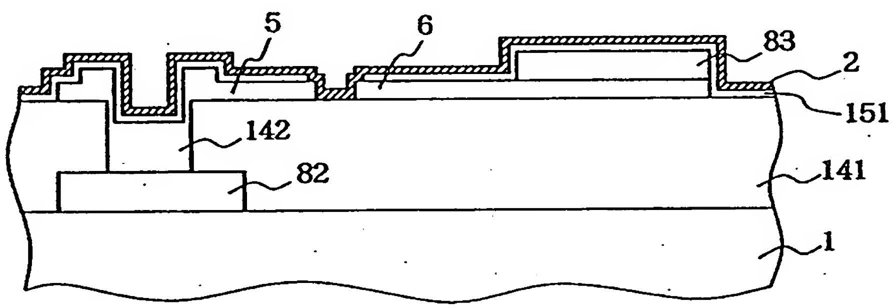
(d)



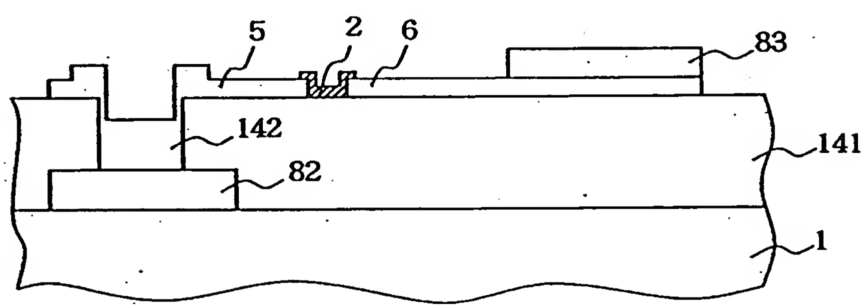
【図１６】
[Fig. 16]



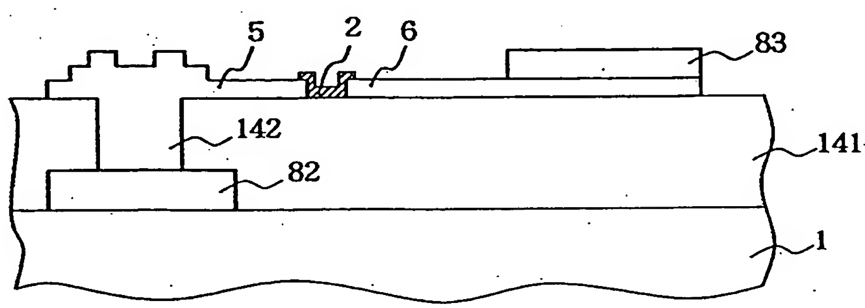
(e)



(f)

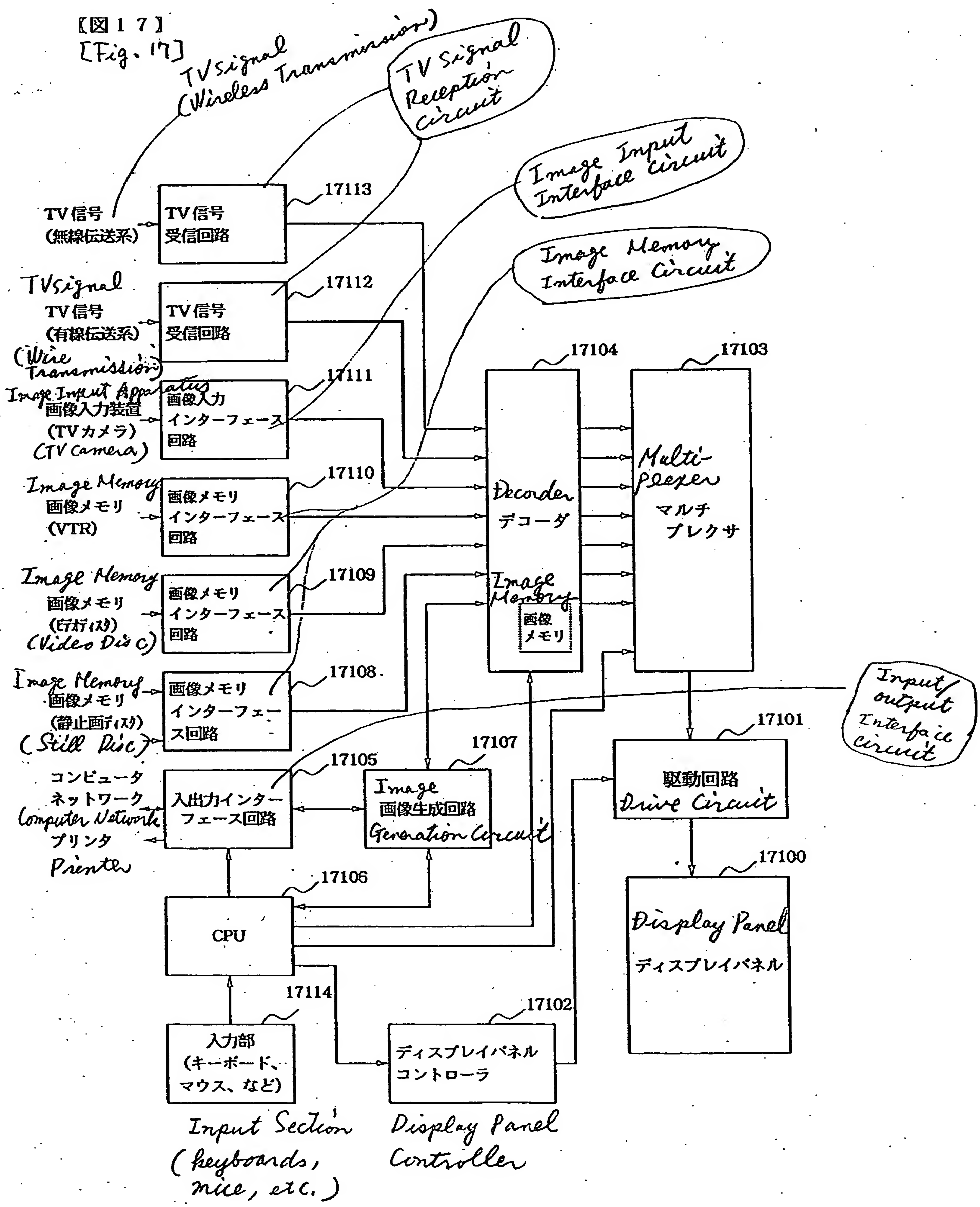


(g)



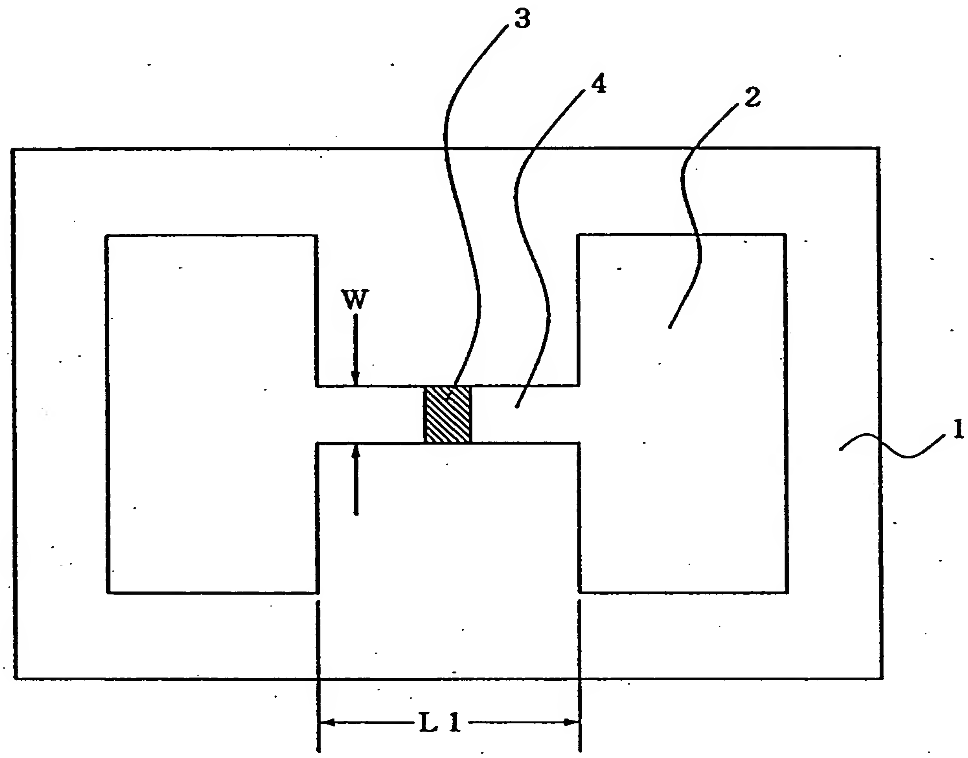
(h)

【図１７】
[Fig. 17]



TV signal (Wireless Transmission)
TV Signal Reception Circuit
Image Input Interface Circuit
Image Memory Interface Circuit
TV信号
(無線伝送系)
TV信号
受信回路
17113
TV signal
TV信号
(有線伝送系)
(Wire Transmission)
TV信号
受信回路
17112
Image Input Apparatus
画像入力装置
(TVカメラ)
(TV camera)
画像入力
インターフェース
回路
17111
Image Memory
画像メモリ
(VTR)
画像メモリ
インターフェース
回路
17110
Image Memory
画像メモリ
(ビデオディスク)
(Video Disc)
画像メモリ
インターフェース
回路
17109
Image Memory
画像メモリ
(静止画ディスク)
(Still Disc)
画像メモリ
インターフェース
回路
17108
17104
Decoder
デコーダ
Image Memory
画像
メモリ
17103
Multi-plexer
マルチ
プレクサ
Input/output Interface circuit
コンピュータ
ネットワーク
Computer Network
プリンタ
Printer
入出力インター
フェース回路
17105
Image
画像生成回路
Generation Circuit
17107
駆動回路
Drive Circuit
17101
17106
CPU
Display Panel
ディスプレイパネル
17100
17114
入力部
(キーボード、
マウス、など)
Input Section (keyboards, mice, etc.)
ディスプレイパネル
コントローラ
17102
Display Panel Controller

【図１８】
[Fig. 18]



[NAME OF THE DOCUMENT] Abstract

[Abstract]

[Object]

To provide a novel and highly efficient electron-emitting device and a method of manufacturing the same, as well as an electron source and an image-forming apparatus using the device.

[Constitution]

An electron-emitting device comprising a pair of oppositely disposed device electrodes and a thin film including an electron-emitting region characterized in that the vicinity of the electron-emitting region is coated with a coat containing carbon as a principal ingredient, and a method of manufacturing the same, as well as an electron source and an image-forming apparatus using the device.

[Elected Drawing] Fig. 6

[Name of Document] Officially Correcting Data

[Amended Document] PATENT APPLICATION

<Recognized Information · Additional Information>

[Applicant]

[Identification No.] 000001007

[Domicile or Residence]

30-2, 3-chome, Shimomaruko, Ohta-ku, Tokyo

[Name] CANON KABUSHIKI KAISHA

[Attorney] Offeror

[Identification No.] 100069877

[Domicile or Residence]

c/o Canon Kabushiki Kaisha
30-2, 3-chome, Shimomaruko, Ohta-ku, Tokyo

[Name] GIICHI MARUSHIMA

Applicant's Information

Identification No. [000001007]

1. Date of Change : August 30, 1990

   (Reason for Change) New Registration

   Address: 30-2, 3-chome, Shimomaruko, Ohta-ku, Tokyo

   Name: CANON KABUSHIKI KAISHA